CANADA

Report of the
National Advisory Board
on Science and Technology

SCIENCE AND TECHNOLOGY, INNOVATION AND NATIONAL PROSPERITY: THE NEED FOR CANADA TO CHANGE COURSE

Presented to the
Prime Minister of Canada

CANADA

Report of the
National Advisory Board
on Science and Technology

SCIENCE AND TECHNOLOGY, INNOVATION AND NATIONAL PROSPERITY: THE NEED FOR CANADA TO CHANGE COURSE

Presented to the
Prime Minister of Canada
April 1991

CANADA

National Advisory Board on Science and Technology

Conseil consultatif national des sciences et de la technologie

April 2, 1991

The Right Honourable Brian Mulroney
Prime Minister of Canada
House of Commons
Room 309-S
Ottawa, Ontario
K1A 0A6

Dear Prime Minister:

I have the honour of transmitting on behalf of NABST the Report of the Committee on National Science and Technology Priorities entitled *Science and Technology, Innovation and National Prosperity: The Need for Canada to Change Course.*

This Report is a diagnostic analysis of the relationship among science and technology, innovation and competitiveness in Canada. It distills the background considerations that have motivated much of the work of the Advisory Board since its inception. The Report therefore provides a context for the more specific recommendations of NABST that are relevant to the broad issue of international competitiveness.

The objective of the Report has been to describe and document the widening gap between the technological fitness of Canadian industry and that of our competitors. The extent and seriousness of this gap must become widely understood so that governments, and Canadians generally, will act with commitment and urgency to change course. To that end, we believe that the Report, either in its entirety or in suitably edited form, should be widely disseminated.

...2

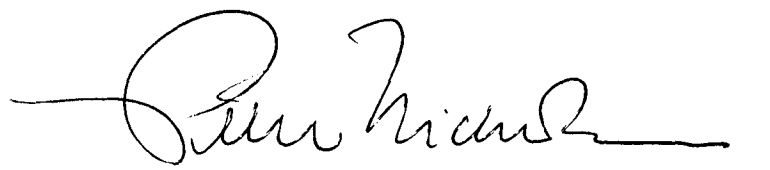
240 Sparks Street
8th Floor West

240, rue Sparks
8e étage ouest

Ottawa, Canada K1A 0H5

Although it was beyond the scope of the Report to offer specific policy recommendations, one overriding conclusion is inescapable. Canadians will not succeed in meeting international competition, and will therefore face a declining relative standard of living, unless we become much more adept in applying science-based technology to create a continuous flow of innovation and productivity growth. There is no more serious challenge facing Canada today. If our economy continues to lose its vitality, all of the fiscal, social and political strains in the federation will become unmanageable. We therefore urge the Government of Canada to accord the highest priority to the matters raised in this Report.

Sincerely,



Peter J. Nicholson
Chairman
Committee on National Science
and Technology Priorities

The views expressed in this paper are those of the authors and do not necessarily correspond to the views or policies of the Government of Canada.

Members of the Committee on National Science and Technology Priorities

Peter J. Nicholson (Chairman)
Senior Vice-President and
Executive Assistant to
the Chairman
The Bank of Nova Scotia
Toronto

Patricia Baird
Chairperson
Royal Commission on
Reproductive Technologies
Vancouver

Gordon Baskerville
Dean
Faculty of Forestry
University of New Brunswick
Fredericton

François Duchesneau
Professor and Director
Department of Philosophy
Université de Montréal
Montreal

Robert O. Fournier
Associate Vice-President (Research)
Dalhousie University
Halifax

William G. Hutchison
Partner
Ernst and Young
Toronto

Léonard LeBlanc
Professor, Departments of Mathematics,
Physics and Computer Science
University of Moncton
Moncton

John MacDonald
Chairman
MacDonald Dettwiler and
Associates Ltd
Richmond

Arthur W. May
President and Vice-Chancellor
Memorial University of Newfoundland
St. John's

J. Fraser Mustard
President
Canadian Institute for
Advanced Research
Toronto

Pierre O. Perron
President
National Research Council
Ottawa

Robert Richardson
Montreal

Advisor:

Lyse Morisset
Senior Advisor
National Advisory Board on
Science and Technology
Ottawa

Consultants:

Mark Murphy
Mark G. Murphy and
Company Limited
Kanata

Roger Miller
Dennis Senik
SECOR Inc.
Montreal

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This Report defines science and technology (S&T) as the set of skills and activities that are linked, through innovation, to increased productivity and which thus underpin economic development in advanced industrialized societies. This report documents the rapidly widening gap between the technological fitness of Canadian industry and that of its industrial country competitors. The extent and seriousness of this gap must become widely understood so that governments, and Canadians generally, will act with commitment and urgency to change course.

- Improvement in the material standard of living in any society is linked ultimately to growth in productivity. Rising productivity in modern industrial economies is increasingly dependent on continuous innovation. Today, innovation and improved technique depend primarily on the systematic application of science-based technology in all facets of the economy. The fundamental importance of this sequential process is the central theme of this report.

- Canada continues to rely heavily on resource exports to provide the surplus with which to purchase technologically sophisticated goods and to pay interest on accumulated external debt. In 1989, Canada generated a trade surplus of $30 billion on forest and mining products alone, but registered a deficit of approximately $22 billion on all other components of merchandise trade. This in itself is of no great concern so long as productivity growth in Canada's resource industries roughly matches that of our trading partners, and average resource prices at least keep pace with the prices of desired imports.

- But what is alarming is the long-term trend in world prices of Canada's resource commodities. Although there have been pronounced cyclical swings, the average prices of Canadian resource-based exports, corrected for inflation, have been declining for at least the past 15 years.

- Canada should not, and indeed cannot, forsake its international comparative advantage in resource products. Faced, however, with long-term declining real prices for most of these commodities, there must be a relentless drive by Canadian firms to improve efficiency in the resource sector and, particularly, to add much greater value to raw materials. This will require a concerted effort by the private sector to apply science-based technology more intensively to increase the pace of innovation in process and product development.

- The Canadian manufacturing sector is showing symptoms of weakness, the causes of which go beyond the present high value of the dollar and adjustment to free trade. For example, the growing deficit in auto parts is indicative of an underlying comparative "disadvantage" in many technology-intensive sectors. This threatens to become more significant as vehicle assemblers demand increased technical sophistication and innovation from their principal suppliers, and as the more labour-intensive segments of industry relocate to low-wage countries.

- The average manufacturing wage rate in Canada, in U.S. dollars, is more than 10% higher than its American counterpart. While Canada's strong dollar is primarily responsible for the latest surge, it must also be recognized that Canadian manufacturing wages (measured in Canadian dollars) have been growing more rapidly than U.S. wages during the past decade. At the same time, Canada's average rate of labour productivity growth has been the *lowest* among the seven principal industrialized countries during the period 1979-89. The gap between Canadian and American manufacturing productivity has thus been widening. This is the most fundamental challenge. This, when combined with the factors just noted, means that the cost-competitiveness of Canadian manufacturers is at an all-time low.

- Canadians may have been lulled into a sense of complacency by recent international assessments that ranked us among the world's most competitive countries, e.g. fifth in 1990, down from fourth in 1989. This indicates that Canada still has a great deal going for it, particularly as regards natural and human resources. But our position has been slipping. In the 1990 assessment by The World Economic Forum (an organization based in Switzerland), Canada ranked 15th among 23 industrialized countries in "outward orientation" (largely reflecting the narrow, U.S. focus of our trade). We placed only 16th in "future orientation" because of the relative lack of technologically advanced, high-growth industries and firms in this country. The message from these figures is that Canada's ranking is low, *and declining*, in precisely those factors of competitiveness that are most important for the future success of high-wage economies in an era of increasing global competition.

- Canadian business and labour leaders appear to be united in the belief that the two most important factors in improving Canadian competitiveness are better training and education and increased research and development (R&D). Where do we stand?

- Expenditures on workplace training in Canada are among the lowest in the industrialized world. The average Canadian worker receives about seven hours of training per year as compared with 200 hours in Japan and 170 in Sweden. Although Canadian governments spend $45 billion annually on public education — among the highest levels in the world relative to GNP — the outcomes are disconcerting. Thirty percent of students drop out before completing high school. University enrolments in physical sciences, math and engineering are declining, as are enrolments in applied technology courses. Meanwhile, industry is facing a widespread shortage of employees with adequate technical skills.

- The basic measure of a nation's R&D effort is the ratio of Gross Expenditure on Research and Development to gross domestic product — the "GERD" ratio. Recent international data indicate that Canada's GERD ratio ranks 17th among the 23 industrialized countries of the Organization for Economic Cooperation and Development (OECD). For example, our relative expenditure falls well behind Norway, a small country with a similarly heavy orientation toward resource industries.

- Of even greater concern than Canada's meagre expenditure on R&D is that our GERD ratio has been *declining*: from 1.4% of GDP in 1986 to 1.3% in 1989. Admittedly, domestic R&D spending is not an infallible indicator of technological fitness. Indeed, Canadian industry benefits enormously from foreign R&D embodied in imported technology. But it is nevertheless alarming that R&D spending in this country is declining, while in most industrial countries it is increasing.

- Canadian industry is partly responsible for this decline. It conducts only 55% of the Country's R&D, a very low figure by industrialized country standards. (And this is superimposed on an already low overall level of R&D spending.) Moreover, the trend has been moving in the wrong direction. In 1986, R&D performed by Canadian industry amounted to 0.78% of GDP; by 1989 the proportion had declined to 0.73%. This is less than half the ratio achieved in most developed countries.

- Canada's weak performance in R&D appears to be due, in about equal measure, to: an industrial structure that is heavily weighted toward industries that perform little R&D, regardless of where in the world they are located (e.g.,resource extractors and processors); and the fact that firms in Canada, with some notable exceptions, conduct less R&D than firms in similar industries in other highly developed countries.

- Among Canadian goods-producing industries, roughly half of private sector R&D expenditure is made by companies that account for less than 5% of sales. These technology-intensive firms have been significantly boosting R&D spending as a proportion of sales, whereas the majority of Canadian goods producers have not. Most significantly, Canada's industrial structure has changed little during the past 20 years, in the sense that the proportion of value added in technology-intensive manufacturing industries has increased only slightly (according to one source, from 30% in 1969 to 32% in 1985). The shift in Japan was from 40% to 60% and in the U.S. it was from 44% to 47% during the same period.

- Canada's low level of R&D spending cannot be explained by industrial structure alone. Equally important is the fact that *within* many industrial sectors, firms in Canada typically spend far less on R&D than their competitors in other countries. (Canadian-owned firms tend to come closer to international averages than those that are foreign-owned, unless the latter have world product mandates.) For example, R&D spending in the Canadian automotive industry, measured as a percentage of sales, is only one-tenth that of the world auto industry. Several other Canadian sectors exhibit similar gaps, while in a few industries — such as aerospace — R&D spending is at least equal to industrial country averages. There is considerable evidence that the low propensity to conduct R&D in Canada is related to the branch-plant status of many of its manufacturers. Other influences, such as a comparatively high cost of capital and a shortage of technically skilled workers, are also likely to be important factors. These matters deserve continued study.

- Although Canada must rely primarily on R&D performed elsewhere and acquired directly or indirectly by firms, it must nevertheless increase its domestic R&D activity for two reasons: 1) to provide high-quality jobs that will inspire more young Canadians to pursue technical careers; 2) because, without a base of indigenous R&D activity, many firms will lack the skills and corporate culture necessary to incorporate state-of-the-art technology and methods, and to embrace continuous innovation.

- This report includes reviews of six industrial sectors — pulp and paper, chemicals, auto parts, aerospace, lasers, computer services and software — to illustrate the diversity of competitive circumstances facing Canadian industry. One common problem is a chronic shortage of technically skilled employees, a situation that threatens to worsen as fewer young Canadians pursue technical education, and as global competition for scientific, engineering and related skills intensifies. There is the prospect of a "brain drain" to the United States as that country seeks to increase its supply of highly qualified personnel through attractive offers to Canada's best and brightest.

- Canadian goods-producing industries may be classified, for purposes of assessing future needs and outlook, into four broad categories.

  (i) There is a group of mature, world-competitive industries — e.g. pulp and paper, mining, auto parts — that risk being caught in a low-value trap. Firms in these sectors are being challenged to rapidly acquire the ability to add much greater value to basic resources or, in the case of auto parts makers, to contribute original engineering and design innovation.

  (ii) A second group includes those firms that have remained truncated as a consequence of foreign ownership and branch-plant status — e.g. many in the chemical, electrical equipment, and consumer goods sectors. They must now export to survive and are therefore challenged to develop globally competitive niches and to adjust rapidly to a free trade environment.

  (iii) A third category — including many large firms in the aerospace, telecommunications and nuclear industries — consists of internationally competitive, technology-based companies in sectors that depend to an important degree on government procurement or on other very large customers. Many firms in this category will not survive in Canada without supportive government policies such as competitive export credit terms and a very favourable R&D and regulatory environment.

  (iv) Finally, there is the high-tech sector, consisting of small firms at the cutting edge of innovation and technology (lasers; computer software; biotechnology). These firms require a steady supply of highly trained people as well as sufficient financial backing, management and marketing skills to make the difficult transition from start-up to mature, internationally competitive exporter. There is a natural complementarity — far too little exploited in Canada — between the skills and needs of these firms and those of large, established companies. The latter possess financial resources and management skills, whereas the former bring technological vitality. Established Canadian firms have not, by and large, linked up with smaller, technology-based firms to foster their development and, in the process, transform this nation's industrial structure into the high-growth industries of the next century.

- This report provides a diagnosis, still incomplete, but clear enough to demonstrate the need for a decisive change of course to reverse the erosion of the base of Canada's economic prosperity. The challenge must be met primarily by Canadians as individuals, and particularly by firms in sectors exposed to global competition. The essential role for government is to establish the most favourable conditions to encourage innovation and productivity. But first, government must provide leadership and a sense of direction.

- It is not easy to identify a set of practical and effective policy measures to address the pervasive problem described in this report. The situation prevailing in Canadian industry was long in gestation and has roots deep in our national psyche. There are no quick or easy answers. Nevertheless, there are at least three directions that Canadians can take with considerable confidence.

  1. Policies that harness S&T to promote innovation and increase productivity must move forward on several fronts simultaneously. The most important of these are:

     - **framework policies** that encourage the application of S&T, including regulatory policies that are conducive to innovation; policies that promote national savings (and thus reduce the cost of capital); policies that promote competition; and policies that facilitate adjustment;

     - **human resources policies** addressing the full spectrum of training and education, with emphasis on inspiring more young people to pursue technical careers; providing much greater management and employee training; and developing in individuals the flexibility to adapt to continuous technological change;

     - policies that promote **the development, acquisition and diffusion** of technology and state-of-the-art industrial practices.

  2. Canada's circumstances suggest that the most urgent S&T challenges for the private sector, with the cooperation of government, are to: a) employ science-based innovation and technology more effectively to increase the value-added in Canada's resource industries, and in the mature manufacturing sector; b) make Canada a more attractive location for the performance of R&D by Canadian and foreign-owned companies; and c) create a climate that encourages the birth, growth and maturation of technologically sophisticated firms in high-potential sectors.

  3. To ensure that policies in the foregoing areas are most effective, governments must engage in continuous consultation with the private sector to develop a shared understanding of the best ways in which science-based technology can be applied in particular sectors and sub-sectors to foster innovation and increased productivity.

- The need for a fundamental change of course in Canada is clear. Canadians must become much more adept at applying science and technology so as to create a continuous flow of innovation and productivity growth. Finding the best path forward will probably require countless incremental steps — a process of trial, error and evaluation. But a determination to change course must be affirmed now. **It is therefore essential that the government accord the highest priority to the matters raised in this report.**

SCIENCE AND TECHNOLOGY, INNOVATION AND NATIONAL PROSPERITY

The Need for Canada to Change Course

This report aims to establish the importance of the links among science and technology, innovation, and national prosperity.[1] Promoting this linkage is the key to increasing productivity in highly developed societies. It lies at the heart of international competitiveness and enables the continuous creation of high-quality jobs. The evidence presented in this report establishes the urgent need to improve dramatically the ability of Canadians to apply science and technology (S&T) to increase the well-being of all citizens. Canada needs a fundamental change of course.

Introduction

In an address delivered August 25, 1989, Prime Minister Brian Mulroney gave eloquent statement to the theme of this report:

> The goal is an economy that can compete with the best in the world, producing stimulating new jobs and new opportunities for future generations of Canadians.... Science and technology are the keys to a modern competitive economy. It is clear that our traditional manufacturing and resource-based industries will no longer assure us a strong position in the global economy if we don't complement them with modern technology.

The orientation of this report emphasizes the role of science and technology in achieving economic objectives through linkages with innovation, productivity and international competitiveness. Of course, technology, and particularly science, have other vital roles in society. Science is of great cultural value in its own right as well as in its more vocational aspects. Science and technology are also of increasing practical importance in improving quality of life through advances in medicine, nutrition, communications, environmental protection — in short, in virtually every aspect of human affairs. Finally, science and technology play a central role in enabling government to fulfill its mandate in many areas, from management of fish stocks to protecting people's health.

None of these roles can be neglected. But the priority for Canada today is to apply science and technology more effectively in order to boost the productivity of our economy. This, ultimately, is the only way to protect and enhance the material quality of life of Canadians.

It must be understood that science and technology are not ends in themselves. In the context of this report, they are essential underpinnings of the process of national development. And while the issues tend to be described in terms that suggest a "business" agenda — terms like competitiveness, labour productivity and economic efficiency — the real objective is to improve the welfare of all citizens.

---

1 This report was drafted by a committee of the National Advisory Board on Science and Technology (NABST) originally charged with recommending national science and technology priorities. From the Committee's work, the need became clear for a statement of the evidence that justifies urgent priority for science and technology policy. This document is the result, and it thus sets the context for the ongoing advice of NABST.

Obviously, achieving this objective relies to a great extent on continued economic success, which provides both satisfying employment and sufficient real income to purchase, often from abroad, goods and services of a quality and quantity that most Canadians demand.

Some people, nevertheless, feel that modern technological society is de-humanizing and that the quest for material progress — propelled by scientific technology and innovation — is leading to environmental catastrophe and spiritual impoverishment. While it is undeniable that science and technology have sometimes been used to serve the dark and acquisitive side of human nature, it is surely wrong to conclude that the solution lies in renouncing technology, even if that were feasible in modern society.

In fact, the wise and humane application of science and technology is essential if we are to protect and restore the environment; to overcome the scourge of many diseases; to enable better communications; to take the danger and drudgery out of countless occupations — in short, if we are to address an increasingly broad range of human concerns. And, fundamentally, the more effective application of science and technology to economic activity is essential if Canadians are to generate sufficient wealth to provide the social, cultural and material standards that the vast majority wants and expects.

The wise application of science and technology is therefore essential to achieving social and economic success. The contemporary importance of S&T in this regard is unprecedented. As the base of human knowledge accumulates exponentially, competition between societies to harness this knowledge will become the driving force creating a new global economy.

How well is Canada prepared to cope in a world where success is being determined by a nation's ability to mobilize its human and capital resources to apply science-based technology to every aspect of economic and social life? Consider the following findings:

- Statistics Canada projects that during the 1986-2000 period, the proportion of Canada's workforce requiring high skill levels (greater than 12 years of education and training) will rise from 45% to over 64%. Unfortunately, the proportion of Canadians acquiring high skill levels is declining.
- In 1987, a Southam survey found that 24% of Canada's adult population was functionally illiterate. Among the highschool graduates in the survey sample, 17% were found to be functionally illiterate, as were 8% of the university graduates.
- One recent survey[2] of scientific attainment in 17 countries showed Canadian high school students finishing near the bottom of the heap — eleventh in biology, eleventh in physics and twelfth in chemistry.
- Comparing Ontario with Japan (per 10,000 workers): Japan has 400 engineers to 112 in Ontario; Japan has 3 accountants to 43 in Ontario; and Japan has 1 lawyer to 39 in Ontario.[3]

---

2 International Association for the Evaluation of Educational Achievement; *Science Achievement in Seventeen Countries*, 1988.

3 Premier's Council of Ontario; *Competing in the New Global Economy*, Vol. I, 1988, p. 222.

Mixed in with these disconcerting statistics is a sprinkling of remarkable Canadian success stories that illustrate what is possible. For example, on February 3, 1990, the *Economist* magazine reported as follows:

> A new fuel additive called Carbonex seems drastically to reduce emissions of particles and of nitrogen oxides. Carbonex was invented by Dr. David Farrar at the University of Toronto and developed by Velino Ventures of Toronto. Researchers found that it reduced emissions of particles from diesel engines by 43% and when added to coal it reduced NOX (oxides of nitrogen) emissions by 25%.

This example, and countless others like it, are encouraging and inspiring. Unfortunately, Canada is not generating enough of them. Does this matter?

The Contemporary Policy Debate

Canada has attained one of the world's highest standards of living, primarily on the basis of raw material extraction and in spite of a relatively weak manufacturing sector. This achievement might justify the view that Canada will continue to succeed despite a feeble indigenous base of industrial science and technology. According to some, if technology is required for more efficient production, it will be purchased by entrepreneurs acting in their own self-interest. In this view, an active government policy to promote the absorption of science and technology in the economy is therefore *not* justified. Indeed, it would be counterproductive if bureaucrats tried to substitute their judgements for those of private business people. The fact that a number of other countries are now overtaking established economic leaders like the U.S. and Canada is not, according to this school of thought, indicative of any particular failure in North America, either of public policy or private initiative. Rather, it is due to the phenomenon of "convergence," as developing countries and the formerly war-torn economies in Japan and Germany catch up with the leaders.[4]

If this were the whole story, one would expect variables like manufacturing productivity to converge and then to evolve at roughly the same rate in all highly developed countries. But the evidence is that productivity in Japan and other technologically-committed countries, having reached North American levels, has continued to diverge. In fact, manufacturing productivity in Canada has shown no tendency to converge to the average of the G-7 countries[5] and has instead lost ground, even to the U.S.

Many observers cannot believe that international competitiveness can be achieved purely through the operation of free market forces on a nation's "natural" comparative advantages. In Harvard professor Michael Porter's words: "National prosperity is created, not inherited."[6] Canada did not build a successful economy during the past 123 years by trusting *entirely* in market forces to take their course. This country has had a great deal of experience with industrial policy — some of it very successful in its time — beginning with the

---

4 There is considerable international evidence of long-run convergence of productivity as laggards adopt the technology of leaders. But there is nothing inevitable in this trend and significant divergence can persist, and grow, for long periods — see, for example, "Increasing Returns and Long-Run Growth"; P.M. Romer; *Journal of Political Economy,* Vol. 94, No. 5, 1986, p. 1002-1037.

5 Canada, France, Germany, Japan, Italy, United Kingdom and the United States.

6 "The Competitive Advantage of Nations"; *Harvard Business Review;* March/April 1990, p.73.

tariff and transportation initiatives of John A. Macdonald; the use of Crown corporations to develop transportation and other infrastructure; the creative application of tax policy to encourage the resource sector; and the use of procurement and monopoly franchises to build powerful utilities and the telecommunications industry.

Although some of these industrial policies would be inappropriate today, it is nevertheless still the case that competitive advantage can be significantly enhanced through conscious policy. The critics of "industrial policy" usually fail to distinguish between those remedies that have outlived their usefulness — and hence deserve criticism — and those, perhaps still undiscovered, that are needed to cope with today's radically changed and dynamic world. The contemporary challenge is to create new policies to ensure that Canada reaps the full potential of science and technology to contribute to a more productive economy and society.

Outline of the report

The Committee has concluded — based on evidence set out in the following pages — that Canada is lagging unacceptably in the application of science and technology in its economy. A gap therefore exists between where we now are and where we have to be to achieve the Prime Minister's goal of creating an economy that can "compete with the best in the world." The existence, or at least the importance, of this gap is not universally acknowledged in government policy circles or in the private sector. Until it is, there is little hope of establishing the consensus needed to raise science and technology — particularly in their relation to innovation, value-added and productivity — to a central position on the national policy agenda. The next section of this report therefore presents evidence confirming Canada's S&T shortcomings and describes some of the consequences of those shortcomings. This diagnostic analysis draws on data primarily at the level of the entire economy.

A subsequent section summarizes many important S&T issues affecting a representative range of economic sectors — aerospace, lasers, computer software, auto parts, chemicals, and pulp and paper. Although the sectoral analyses tend to confirm the implications of the macro-statistics, they also begin to reveal the industry-specific circumstances and demonstrate that effective policy must be tailored to these special circumstances. But the appropriate measures and priorities can only be determined with the help of detailed and continuing consultation — of the sort now taking place between the federal government and the auto parts industry, for example.

The final section of the report summarizes the main implications of the diagnostic material, with conclusions as to broad themes for science and technology policy development.

Canadian Competitiveness: A Diagnosis

An appropriate definition of competitiveness might be the one proposed by the U.S. Presidential Commission on Industrial Competitiveness:

> Competitiveness is the degree to which a nation can, under fair market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining and expanding the real incomes of its citizens.

In this sense, competitiveness is linked ultimately to improved productivity — i.e. the ability to more *efficiently* combine all the resources of our economy to produce those things desired by Canadians and by our trading partners. Productivity improvement today is increasingly dependent on continuous innovation. Finally, innovation and improved technique depend to a rapidly increasing degree on the systematic application of scientific technology throughout all facets of the economy. The fundamental importance of this linked process is the central theme of this report.

In the words of Prime Minister Brian Mulroney cited earlier: "The goal is an economy that can compete with the best in the world.... Our traditional manufacturing and resource-based industries will no longer assure us a strong position in the global economy if we don't complement them with modern technology."

The purpose of this section is to demonstrate that a large gap exists between the current performance and direction of Canada's economy and the goal articulated by the Prime Minister. The evidence consists of a number of indicators that compare Canada with other highly developed countries and that illustrate several significant long-run trends in the economy. Although each indicator has its limitations, the evidence, when viewed in its entirety, conveys an inescapable message — the present course of Canada's economy is not equipping it to compete with the best in the world.

Evidently, Canada's economic difficulties are not due solely to the inadequate application of science and technology. The complete story is a complex, interlinked set of causes and consequences that have historical, cultural and institutional origins. The special significance of science and technology is that high-wage economies have been forced to rely increasingly on the continuous creation and adaptation of innovation based on S&T as their principal source of comparative advantage. Those who have mastered this process and its techniques are gaining a widening advantage in global competition. The words "science and technology" may not be the best choice in this context because they conjure up images of people in lab coats engrossed in esoteric pursuits. New language and new images are needed to convey to Canadians the much broader conception of S&T as the set of skills and tools that are the cutting edge of continued economic development in modern societies.

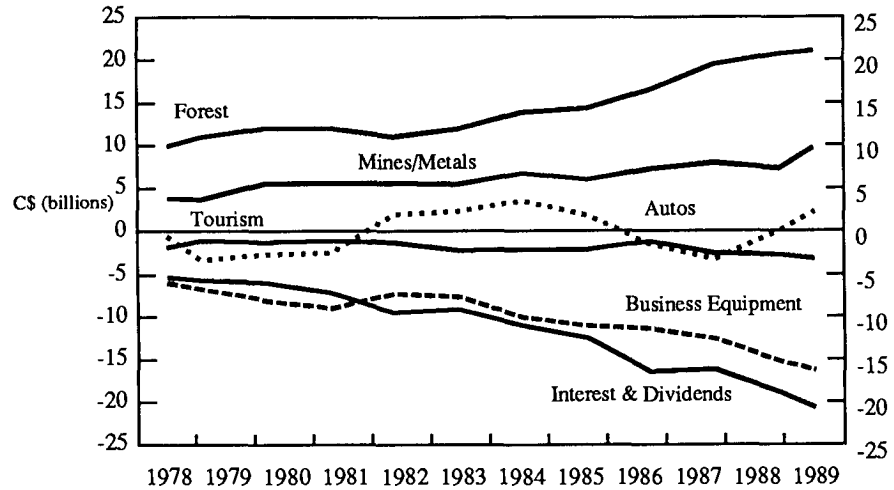
Some Perspectives on External Trade

Export competitiveness is vital for Canada not only because of the number of dependent jobs (exports account for 20-25% of GDP and for more than one-third of total private-sector output) but more particularly because it is only through a high volume of international trade that Canadians can acquire many of the things that are taken for granted in modern life — jet aircraft, consumer electronics, modern production machinery, medical equipment and the latest pharmaceuticals. And while some imports can be, and often are, replaced by domestic production, the doctrine of comparative advantage teaches that Canadians as a whole will be better off if we trade what we do best for those things that others do best.

If Canadian enterprises fail to keep pace with the productivity of our trading partners and if we fail to upgrade the value of our exports to the same extent, then the purchasing power of those exports in terms of desired imports will decline. Canadians will thus become poorer, at least relative to the citizens of the more productive societies.

A number of the key components of Canada's present trade picture are traced in Figure 1, covering the period 1978-89. This illustrates our continued heavy reliance on resource exports to generate the trade surplus needed to purchase technologically sophisticated goods and to pay interest on accumulated external debt. The surplus on forest and mining products alone — approximately $30 billion in 1989 — offset a deficit of roughly $22 billion on all other components of merchandise trade. Although manufactured goods form

Figure 1. Trade Balance — Major Components (1978-1989)
(Balance-of-payments basis)



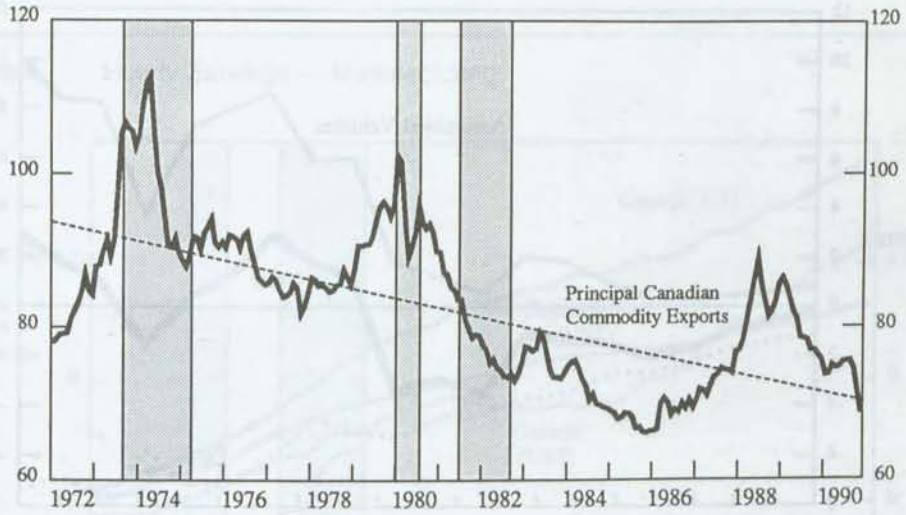
Source: Statistics Canada.

an increasing share of Canada's exports — about 55% in 1989, up from 40% in 1980 — resources still contribute by far the greatest share of the trade *surplus*. This surplus simply indicates that Canada's international comparative advantage continues to reside, as it traditionally has, in resource exploitation. This in itself is not of concern so long as productivity growth in Canada's resource industries roughly matches that of our trading partners, and as long as average resource prices at least keep pace with the prices of desired imports.

Some analysts see benefit in the growing deficit in business equipment since it represents the acquisition of advanced technology by Canadian business, the returns on which will show up in higher growth and improved export performance in the future. There is an important element of truth in this observation. But the fact remains that Canada continues to rely to an extraordinary degree on natural resources — to which we add relatively little value — to earn the foreign exchange needed to acquire technology.

Any complacency results from people assuming that resource products will continue to deliver the required increasing surpluses. Figure 2 shows that the real prices — i.e. after subtracting inflation — of Canada's export commodities have been on a gradual declining trend for at least the last 15 years. (The price index is trade-weighted, with the average price level in 1974 defined as 100.) Although the cyclical effect of recessions has produced dramatic swings, the long-term downtrend is unmistakable.

Figure 2. All-commodity Price Index
(Inflation-adjusted)
Index: 1974=100



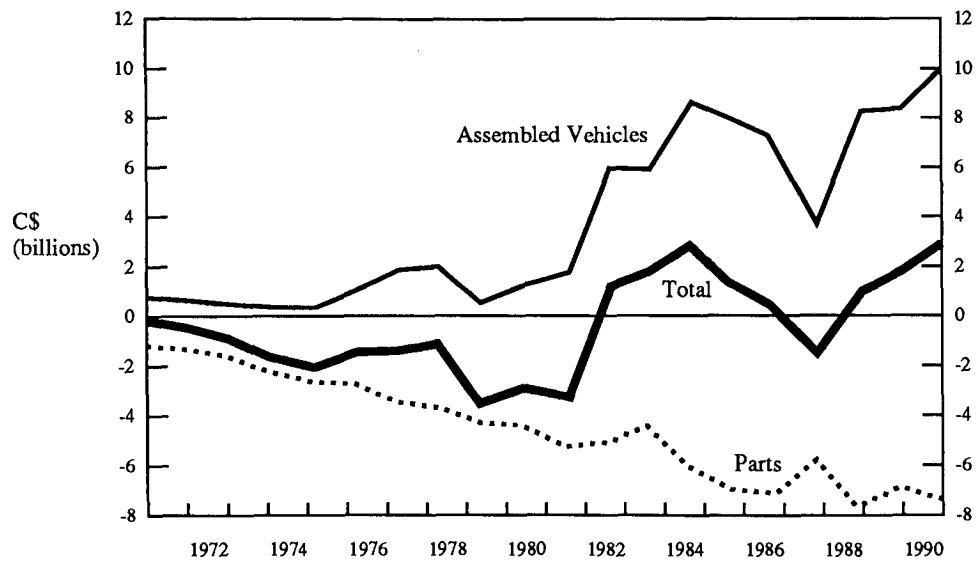
Shaded areas indicate U.S. recession periods.
Source: Scotiabank Commodity Price Index.

The price erosion is due fundamentally to the development of new sources of supply (primarily in developing countries) and to the invention of a number of substitute products and materials resulting from the application of science-based technology. Worldwide, the consumption of resource commodities has been declining steadily as a proportion of total output. As investment capital begins to return to developing countries in Asia and Latin America, and as developments in materials science continue to accumulate, the underlying decline of world prices for resource-based products is likely to continue, and may even accelerate.

Canada must nevertheless continue to rely heavily on its natural resources for the foreseeable future. Faced with long-term falling real prices for most of these resources, as well as the fact that Canada has exhausted many of its cheapest supplies, the only practical ways to adjust — other than by accepting declining living standards — are: to add greater value to resource products; to improve process efficiency in the resource sector; and to aggressively diversify the economy toward production of higher-margin goods and services. All three responses are needed and all three require a concerted effort to apply science and technology to enhance economic value.

The core of Canada's manufacturing sector — and a source of much of the manufacturing export growth during the past decade — is the automobile industry. In 1989, the export value of assembled vehicles and parts was $34.7 billion or almost 25% of total Canadian exports.[7] Figure 3 shows that the net balance of automotive trade is composed of a surplus in assembled vehicles ($8.7 billion in 1989) and a persistent and growing deficit in parts ($6.0 billion in 1989).

Figure 3. Canada-World Auto Trade Balances



1990 based on first eleven months, annual rate.
Source: Statistics Canada

The assembly of vehicles in Canada relies almost exclusively on imported technology in the form of assembly lines that have no intrinsic connection to Canada's indigenous technological base. The automotive parts sector, by contrast, consists of a very large number of small - and medium-size suppliers and represents "grass roots" technological capability. The persistent and growing deficit in auto parts is a disturbing indicator of the relative weakness of Canada's indigenous manufacturing capability. This comparative "disadvantage" threatens to become even more significant as vehicle assembly companies demand increasing technical sophistication and design innovation from their principal parts suppliers and as the more labour-intensive segments of the industry relocate to low-wage countries.

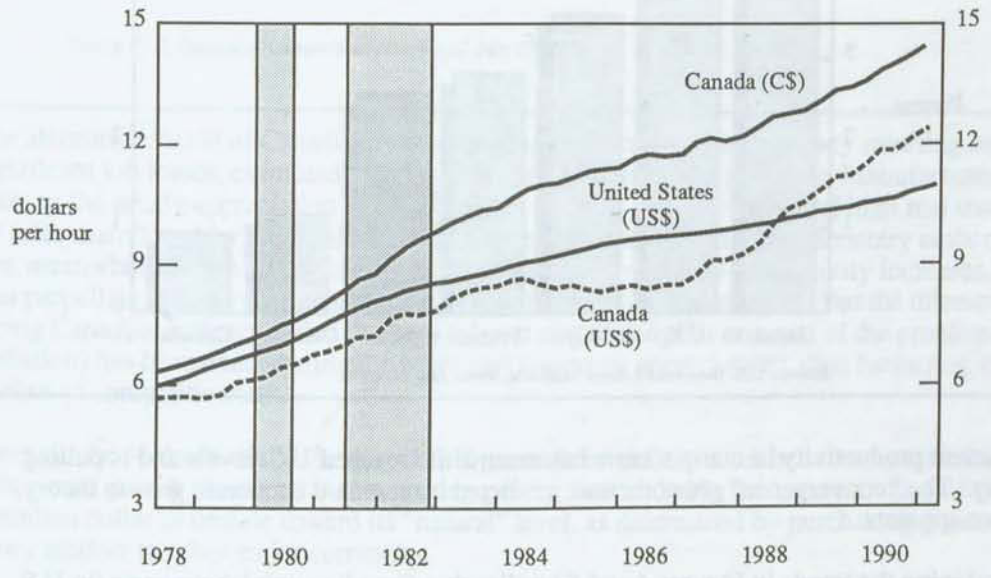
7 Trade statistics in the Report are from the Bank of Canada Review (September 1990), unless otherwise indicated.

A Perspective on Productivity

A fundamental indicator of international competitiveness, particularly in the manufacturing sector, is unit labour cost.[8] This is defined as the average wage rate (usually expressed in U.S. dollars to permit international comparison) divided by physical output per unit of time. In the steel industry, for example, it might be average factory wages in dollars per hour divided by tons of steel per hour. The following figures trace the components of Canada's unit labour cost performance over time and relative to other highly developed countries.

Figure 4 shows that the rate of increase of average manufacturing wages in Canada (the upper line) has exceeded the comparable rate in the U.S. (the middle line) since 1981.

Figure 4. Hourly Earnings — Manufacturing



Shaded area indicates recession periods.
Source: Statistics Canada and U.S. Bureau of Labour Statistics

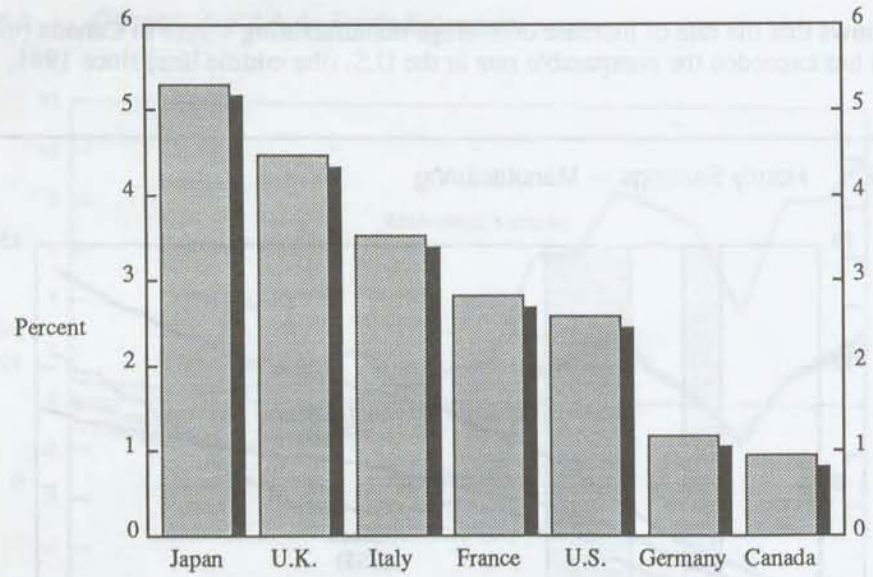
For a time, the divergence in underlying domestic wage growth was more than offset by the devaluation of the Canadian dollar, which had fallen to about U.S. 70 cents in 1986. (This was, of course, not without cost since it made most imports correspondingly more expensive.) Since 1986, the Canadian dollar has appreciated by more than 20%, thus compounding the effect of the rapid rise of (domestic currency) wage rates in this country. The average manufacturing wage rate in Canada, in U.S. dollars, is now more than 10% higher than its American counterpart. The growing labour cost disparity has been exacerbated by slow productivity growth in Canada.

---

8 The service sector today accounts for the majority of national output and for approximately 75% of employment in Canada. But productivity and cost data for many services are poorly developed or simply unavailable. Therefore, by necessity, most of the statistical material and associated analysis in the report refers to goods-producing industries. It should be emphasized, however, that an increasing number of services, such as consulting, banking, marketing and advertising, are "traded" and are thus directly exposed to international competition. In every case, command of technology and innovation are increasingly important requirements for success.

Figure 5 shows that Canadian manufacturing productivity increases during the past decade have lagged significantly behind all the other members of the G-7. Canada's absolute levels of labour productivity in most manufacturing sectors have always been below those in the U.S. The stagnant productivity growth in Canada means that this gap has been widening.[9]

Figure 5. Growth of Labour Productivity in Manufacturing (1979-1989)
(average annual rate of change in output per hour)



Source: U.S. Bureau of Labour Statistics, *News*, July 27, 1990.

Japanese productivity in many sectors has meanwhile reached U.S. levels and is pulling away. The "convergence" phenomenon, predicted by standard economic growth theory, is not apparent.

Combining the trends in Figures 4 and 5 implies that Canadian unit labour costs (in U.S. dollars) have diverged sharply from those of our principal industrial competitors. Figure 6 shows that unit costs in manufacturing grew 10.4% in 1989, far more than those of any G-7 country. Nor was 1989 an isolated year. Between 1986 and 1989, manufacturing unit labour costs increased 31.6% in Canada as compared with only 2.4% in the U.S. Approximately 60% of the deterioration in Canada's position was caused by the appreciation of the Canadian dollar. The remainder was caused by higher rates of wage growth in this country, compounded by weaker growth of labour productivity.[10]

These adverse trends in Canada's unit-cost competitiveness could not have come at a worse time, in view of the need to adjust rapidly to the opportunities and threats created by the Canada - U.S. Free Trade Agreement. Canada's failure to provide an attractive environment for manufacturing investment is undermining the fundamental objectives of the FTA, and risks accelerated deindustrialization.

---

9 Low labour productivity must not be equated with sloth and laziness. The productivity of labour depends on a great many factors, of which management and, particularly, technology tend to be the most important.

Figure 6. Percentage Increase in Manufacturing Unit Labour Costs – 1988 to 1989

	In Domestic Currency	In U.S. Dollars
Canada	6.6	10.8
United States	1.3	1.3
Japan	0.9	-6.3
Germany	0.0	-6.6
France	-0.1	-6.6
U.K.	4.8	-3.6
Italy	7.7	2.2

Source: U.S. Bureau of Labour Statistics, *News*, July 27, 1990.

The alarming erosion of Canadian manufacturing competitiveness is already resulting in significant job losses, estimated to be at least 180,000 during the past year. Manufacturers point to the steady appreciation of the Canadian dollar — a consequence of high real interest rates maintained by the Bank of Canada — as the main culprit. The monetary authorities, meanwhile, blame wage settlements that continue to outstrip productivity increases, thus propelling inflation and eroding cost competitiveness. Both are right. But the dilemma facing Canadian industry is that the high interest rate remedy for one part of the problem (inflation) has been exacerbating the other part (currency appreciation), thus furthering the decline of competitiveness.

There can be no doubt that wage growth and government deficits must be severely restrained. This would permit a more relaxed monetary policy, thus allowing the external value of the Canadian dollar to decline toward its "natural" level, as determined by purchasing power parity relative to other major currencies.

These issues are understandably preoccupying the monetary and fiscal authorities because their successful management has become an urgent necessary condition for Canada's economic recovery. But their successful management is by no means sufficient in the longer run. The preoccupation of economic policy makers with the traditional macroeconomic variables has unfortunately diverted attention from the more fundamental challenge. The ultimate goal of greater prosperity can only be achieved by increased productivity and by adding more value to the things Canadians produce, whether goods or services. The central theme of this report is that satisfactory growth in productivity in modern industrialized economies depends on continuous innovation resulting primarily from the application of science-based technology.

---

10 *Quarterly Labour Market and Productivity Review;* Canadian Labour Market and Productivity Centre; Summer 1990, p. 20.

Sources of Competitiveness

By most absolute international standards, Canada is still one of the world's most economically successful countries. Recent studies of income per capita, based on careful inter-country measures of purchasing power parity, indicate that Canada ranks second only to the United States and continues to be significantly more affluent than Japan and western European countries. It is therefore hardly surprising that most Canadians have been complacent about the global economic challenge. Complacency may also result from recent assessments of international competitiveness carried out by the World Economic Forum (WEF).[11] In the 1990 survey, Canada ranked a very respectable fifth overall behind Japan, Switzerland, the U.S. and Germany (Figure 7).

Figure 7. Competitiveness Ranking

1986	1989	1990
1. Japan	1. Japan	1. Japan
2. U.S.A	2. Switzerland	2. Switzerland
3. Switzerland	3. U.S.A	3. U.S.A
4. Germany	4. CANADA	4. Germany
5. Denmark	5. Germany	5. CANADA
6. CANADA	6. Finland	6. Sweden
7. Sweden	7. Netherlands	7. Finland
8. Netherlands	8. Sweden	8. Denmark
9. Norway	9. Norway	9. Norway
10. Finland	10. Australia	10. Netherlands

Source: The World Competitiveness Report (WEF)

The WEF developed its competitiveness index by combining the ranking on the 10 components listed in Figure 8. Canada scores consistently high in terms of natural resource endowment (second only to Norway) and human resources (due to the relative youth and education level of the labour force and despite a weakness in technical training). Recent government policies promoting privatization and deregulation have boosted Canada's standing. At least until recently, political stability was also a clear plus.

Although these rankings indicate some important strengths, they provide no justification for complacency. In the latest survey, Canada has slipped in several components. These reflect: a serious decline in industrial efficiency (the escalation of unit labour costs documented above) and continued erosion of Canada's perceived "outward orientation" and "future orientation," which are now ranked 15th and 16th, respectively, among 23 industrialized countries. These dismal assessments reflect the extremely narrow focus of Canada's

11 The WEF is an organization based in Geneva. The assessment is a mixture of objective measures together with opinion data sampled from an international cross section of business people and experts. It contains a large subjective component.

trade (75% of exports go to the U.S.), and the poor representation of technologically advanced, high-growth industries and firms in Canada. It is of particular concern that the components of competitiveness where Canada's ranking has been lowest are precisely those that are most important for the future success of high-wage economies in an era of increasing global trade competition. Our ranking in these areas has been steadily declining.

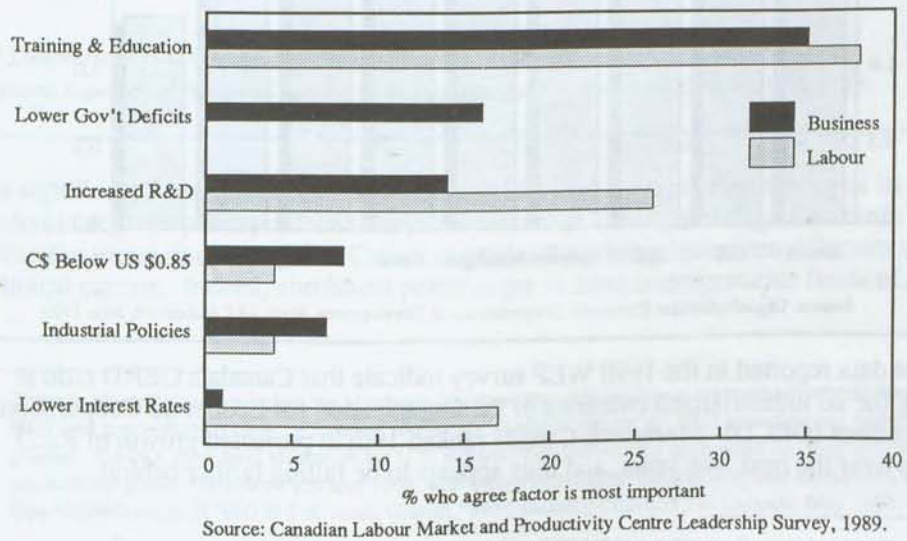
Figure 8. Canada's Ranking on Factors of Competitiveness*

	Rank 1986	Rank 1989	Rank 1990
Natural Endowment	3	2	2
Human Resources	4	2	3
Dynamism of Economy	7	3	5
State Interference	8	3	6
Dynamics of Market	7	4	5
Industrial Efficiency	8	4	13
Socio-Political Stability	7	6	8
Financial Dynamism	7	11	10
Outward Orientation	12	14	15
Future Orientation	9	15	16
Overall	6	4	5

*Ranking of 23 industrialized countries.
Source: The World Competitiveness Report (WEF)

The Canadian Labour Market and Productivity Centre (CLMPC) regularly surveys a sample of business and labour leaders. Figure 9 illustrates the views of this group as to the most important factors in improving Canadian competitiveness. (The scale is the percentage of each group identifying a particular factor as the single most important. The percentages do not add up to 100 because the less important factors are not listed.)

Figure 9. Most Important Factor in Improving Canadian Competitiveness



Source: Canadian Labour Market and Productivity Centre Leadership Survey, 1989.

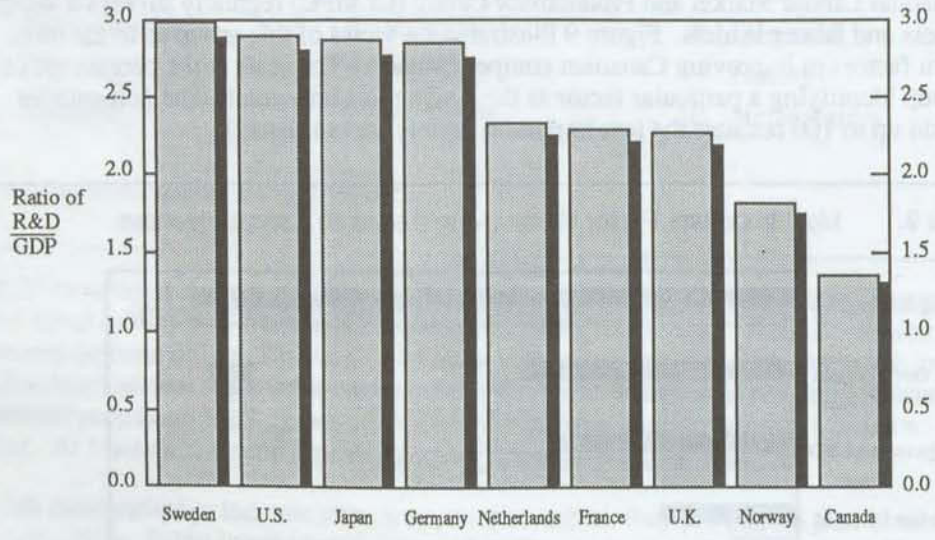
The most important factor for both business and labour leaders is training and education. The need for lower deficits (solely a business concern) and lower interest rates (solely a labour concern) were frequently mentioned. But because both are opposite sides of essentially the same coin, the business/labour divergence is more apparent than real. Perhaps surprisingly, neither business nor labour appears to have much faith in "industrial policy," apparently reflecting a nearly universal skepticism of the efficacy of directed intervention by government.

After training and education, the most important source of increased competitiveness, particularly in labour's view, is increased research and development. Business leaders may have placed less emphasis on this factor if they were from industries where R&D plays only a small role, or from branch plants without an R&D mandate. And since R&D decisions are the responsibility of business management, it might be expected that labour leaders would be more inclined than business leaders to see it as a shortcoming in present practice.

A Perspective on Research and Development[12]

The basic measure of a nation's R&D effort is the so-called GERD to GDP ratio, the Gross Expenditure on Research and Development as a percentage of Gross Domestic Product. By this measure (Figure 10), Canada ranks well behind most other industrialized countries, spending less than half the relative amount on R&D as such countries as Japan, Sweden and Germany. (In none of these cases is defense-related R&D spending a significant factor.)

Figure 10. Research and Development Expenditures as a Percentage of Gross Domestic Product
International comparisons for 1987



Source: Organization for Economic Cooperation and Development, *Main S&T Indicators*, June 1990.

More recent data reported in the 1990 WEF survey indicate that Canada's GERD ratio is 17th among the 23 industrialized countries of the Organization for Economic Cooperation and Development (OECD). Moreover, Canada ranked 19th in projected growth of R&D expenditure over the next five years, and thus appears to be falling farther behind.

12 Since the reports of other Committees of NABST will deal with matters related to training and education, as well as factors bearing on the cost of capital, it is important here to examine in greater detail Canada's R&D performance.

It is important to note that R&D spending is a measure of only one input to the productive process. It has, at most, an indirect correlation with competitiveness and export success.[13] As already illustrated in Figure 1, Canada imports a great deal of R&D embodied in advanced machinery and equipment. Thus low indigenous spending on R&D does not necessarily point to technological backwardness.

Nevertheless, the picture that emerges from Figure 10 is at least consistent with other indicators of lagging competitiveness — e.g. poor manufacturing productivity growth and persistent trade deficits (i.e. comparative disadvantage) in most sophisticated manufacturing sectors. Even Norway, with its small and heavily resource-dependent economy, appears to be allocating a significantly higher proportion of its resources to R&D than Canada does.

A more detailed perspective is provided in Figure 11, which ranks Canada among eight highly developed countries (on a range of indicators). Note that the amount of R&D performed by government in Canada is about average. But also note that the amount of R&D funded by industry is at the bottom of the ranking.

Figure 11. Comparative Ranking of Canadian R&D Performance (1986)

	Ranking*
R&D as a percent of GDP	Lowest
Industry-funded R&D/GDP	Lowest
Government-funded R&D/GDP	2nd Lowest
Government-performed R&D/GDP	Middle
Higher Education R&D/GDP	2nd Lowest
Advanced Degrees (by Pop.)	Middle
Scientists & engineers (by Pop.)	Lowest
International patents (by Pop.)	Lowest
Number of technology-intensive industries with positive trade balance	Lowest

* Canada, Japan, U.S., Germany, France, Sweden, U.K., Netherlands

Source: Report of the Premier's Council (Ontario) *Competing in the New Global Economy*, 1990, p. 201.

It is significant that Canada does not lag behind its peer group in the number of its advanced academic degrees per capita. But the proportion of scientists and engineers ranks last within the group, indicating that Canadian graduate students have been reluctant to pursue technical careers. Indeed, enrolment percentages in most undergraduate fields of science

13 There is nevertheless considerable academic literature that demonstrates a strong correlation between R&D and productivity growth. Estimates of the "social rate of return" on R&D spending are typically 40% or greater. Careful, long-term studies in the U.S. suggest that technology accounted for roughly 60% of productivity growth between 1929 and 1969, with labour and capital contributing only about 20% each. See "Contributions of R&D to Economic Growth," W.H. Gauvin; *Chemistry in Canada*; May 1981, pp. 14-26.

and engineering in Canadian universities have been declining.[14] Very few leaders in Canadian business or politics have come from science or engineering backgrounds, in sharp contrast with the situation in Japan, Germany and even Sweden and Italy. Most of Canada's business role models are lawyers, MBAs and marketing professionals.

Although Canadians perform only about 2% of the world's R&D, they are authors of approximately twice that percentage of all scientific papers. Japan, on the other hand, was responsible (in the mid-1980s) for about 17% of world R&D but only 8% of the scientific literature. In fact, Germany, France and the U.S. each accounted for a larger percentage of R&D than of scientific papers. The output of academic science is evidently not closely correlated with commercial application.

It is frequently observed that the United States and Britain have been losing the competitive race to Japan and Germany, despite making many of the scientific breakthroughs that underpin today's most technologically advanced industries. (The computer chip and the VCR are spectacular examples.) The key requirement for economic success is the ability of firms to translate basic innovations into products that can be economically and reliably produced. Although it is necessary for a nation to possess the basic scientific ability to comprehend leading edge technology and to impart scientific and engineering skills through its educational system, this is clearly not sufficient to guarantee economic success. The ability to translate scientific and technical know-how into process and product innovations that satisfy customer needs is even more important. As one measure of success in this regard, Japan's share of U.S. patents increased from 4% in 1970 to 20% in 1987, while the U.S. share declined by a corresponding amount. Canada's share of U.S. patents, meanwhile, remained almost unchanged at slightly under 2%.

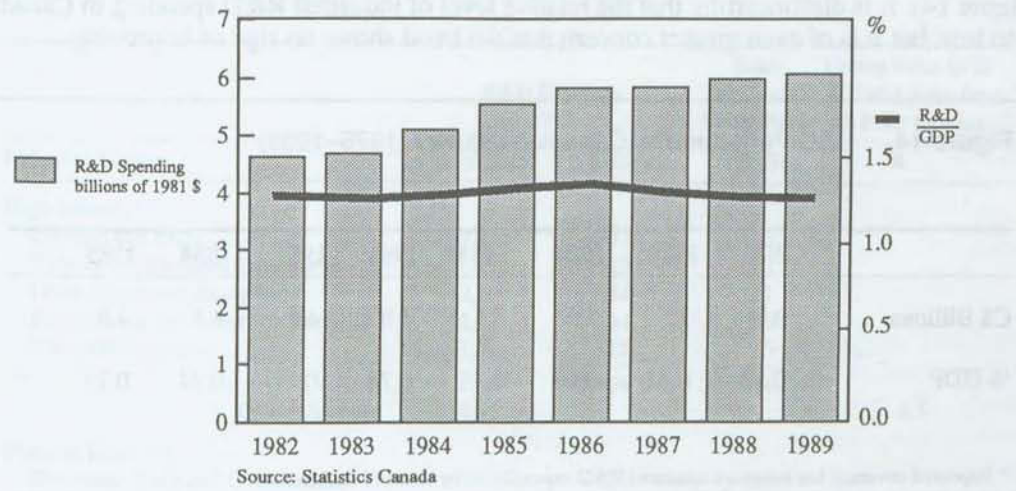
We have seen (Figure 10) that the GERD to GDP ratio for Canada was well below its industrial country peer group in 1987. Figure 12 shows that the ratio has been declining steadily since 1986, and had fallen to 1.3% by 1989. Research and Development spending (in constant dollars) has increased only slightly during the past four years, despite strong growth in the economy as a whole. Although the GERD ratio has limitations as a static indicator of competitiveness, it is puzzling and alarming that it should be *declining* in Canada while tending to increase in the other competitively successful advanced economies. In view of the long-term downtrend of resource prices and sluggish manufacturing productivity growth noted earlier, it should be of great concern that R&D spending in Canada has stagnated.

To illustrate the extent to which Canada has fallen behind, suppose that Canada sought to increase the GERD ratio to 2.25% by the end of the decade. Assuming that nominal GDP increases at an annual average rate of 7%, R&D spending would have to increase at a compound average annual rate of 13.2% for 10 years. It is questionable — given the nature of Canada's industrial structure — whether this rate of growth could be efficiently absorbed, even though the target of 2.25% of GDP is a modest one compared with other industrialized countries.

---

14 For example, undergraduate enrolment in engineering, mathematics and physical sciences in Ontario universities declined each year from 1984 to 1987, in absolute numbers and as a percentage of total enrolment. Moreover, the proportion of Ontario university applicants citing engineering, math or science as their first choice for major declined steadily from 31.3% in 1983 to 24.1% in 1988. (Source: "People & Skills in the New Global Economy"; *Report of the Premier's Council of Ontario*; 1990; p. 75.)

Figure 12. R&D Spending in Canada (1982-1989)



Source: Statistics Canada

Figure 13 provides a cross-national perspective on the amount of R&D performed by private industry, governments and academic institutions. (Rows of the table add up to 100%.) The proportion performed in universities is roughly comparable in the six countries listed. In Canada and Australia, a significantly higher proportion of R&D is performed by government and a correspondingly lower percentage by industry.[15] The amount of R&D actually *funded* by industry in Canada is considerably lower than the table indicates — 42% of the total in 1986, while governments funded 38%. These percentages remained essentially unchanged in 1989.

Figure 13. Who Performs R&D?

(Percentage of Total R&D Spending: 1986)

	Industry	Government	Universities
Canada	54	24	22
Sweden	73	4	22
Germany	73	14	13
U.S.	70	15	15
Japan	67	13	20
Australia	35	38	27

Source: Organization for Economic Cooperation and Development (OECD), *Main S&T Indicators*, Dec. 1988.

15 Although the *proportion* of R&D performed by government and universities in Canada compares favourably with other countries, recall that total R&D relative to GDP is only about half the level of most other highly industrialized countries. Thus R&D performance, both in government and in university labs, makes up a smaller proportion of GDP in Canada than in most other advanced countries.

The amount of R&D performed by Canadian industry, relative to national output, has remained almost constant since 1984 and, if anything, has recently declined slightly (Figure 14). It is disconcerting that the relative level of industrial R&D spending in Canada is so low, but it is of even greater concern that the trend shows no sign of improving.

Figure 14. R&D Performed by Canadian Industry (1975–1989)

	1975	1980	1984	1985*	1986	1987	1988	1989
C$ Billions	0.7	1.6	3.0	3.6	4.0	4.2	4.5	4.8
% GDP	0.40	0.51	0.67	0.76	0.78	0.77	0.74	0.73

* Improved coverage has increased measured R&D expenditures by about 10% after 1984.

Source: Statistics Canada

Why is Canadian R&D so Low?

Canadian industry conducts little R&D for two equally important reasons. First, the Canadian economy is dominated by industries that have intrinsically low ratios of R&D spending to output. Part of Canada's low ratio is therefore due to industrial structure. Second, goods-producing industries in Canada (with some notable exceptions) tend to perform less R&D than similar industries in other highly developed countries. Thus, while part of the R&D shortfall can be explained by Canada's industrial structure, a significant portion of the gap is due to the low "propensity" of many Canadian firms to conduct R&D, as compared with their counterparts in other industrialized countries.

The effect of industrial structure is illustrated in Figure 15 (see next page), which divides Canada's goods-producing industries into three broad categories according to R&D expenditure as a percentage of sales.

In the "high intensity" group, expenditures in 1987 averaged 14.4% of sales or $1.7 billion. The ratio drops sharply to 3.4% of sales in the "medium intensity" group, whereas the "low intensity" industries, namely the traditional manufacturing sector and resource producers, devoted only about 0.6% of sales to R&D. Put another way, the high intensity group of industries accounted for almost 50% of total R&D spending, but only 4.5% of the sales of all companies in the sample. At the other end of the spectrum, the so-called "low end" industries accounted for over 72% of sales, but only 22% of R&D spending.

Figure 15. Effect of Industrial Structure (1987 Data)

Industry Group	R&D Expenses 1987 as % of Sales	R&D Expenses 1987 $ Million	Sales of Firms Doing R&D $ Billion	Group Sales as % of Total Sales for all Four Groups %
High Intensity				
Aircraft and Parts	17.1	432	2.5	
Telecommunications Equipment	16.9	549	3.2	
Other Electronic Equipment	12.0	254	2.1	
Engineering and Scientific Services	11.9	294	2.5	
Computer Services	11.7	175	1.5	
		1,704	11.8	
Group Average	14.4			4.5
Medium Intensity				
Electronic Parts and Components	5.9	24	0.4	
Business Machines	3.7	216	5.8	
Drugs and Medicines	3.5	95	2.7	
Machinery	3.2	72	2.3	
Scientific and Professional Equipment	2.5	36	1.4	
Other Manufacturing Industries	2.3	29	1.3	
		472	13.9	
Group Average	3.4			5.3
Low Intensity				
"High End"				
Other Electrical Products	1.5	58	3.9	
Primary Metals, non-ferrous	1.3	96	7.4	
Other Chemical Products	1.2	151	12.6	
Textiles	1.1	36	3.3	
Metal Fabricating	1.1	29	2.6	
Electrical Power	1.0	170	17.0	
		540	46.8	
Group Average	1.2			17.9
"Low End"				
Other Non-Manufacturing Industries	0.9	189	21.0	
Rubber and Plastics Products	0.7	16	2.3	
Mining	0.6	43	7.2	
Wood	0.6	22	3.7	
Crude Petroleum and Natural Gas	0.5	26	5.2	
Refined Petroleum and Coal Products	0.5	105	21.0	
Transportation and Other Utilities	0.4	111	27.8	
Non-Metallic Mineral Products	0.4	13	3.3	
Pulp and Paper	0.3	69	23.0	
Primary Metals, ferrous	0.3	26	8.7	
Other Transportation Equipment	0.3	93	31.0	
Food, Beverages and Tobacco	0.2	70	35.0	
		783	189.2	
Group Average	0.4			72.3
Average for all sectors	1.3			
		3,501	261.7	100.00

Source: Statistics Canada #88-202, Table 15 (1987), Table 13 (1977)

Figure 15 shows that most of the industries that dominate Canada's economy do little R&D. For example, the pulp and paper sector devotes only about 0.3% of sales and the energy sector about 0.5% of sales to R&D. Viewed over time, the high intensity group of industries has been significantly boosting R&D spending relative to sales but there has been little, if any, increase in the overall ratio for the low intensity group. Meanwhile, Canada's industrial structure has changed remarkably little during the past 20 years, in the sense that the proportion of manufacturing value-added in technology-intensive industries has increased only slightly. According to one source,[16] the share of value-added in technology-intensive goods in Canada was 30% in 1969 and had increased to only 32% by 1985. By contrast, the comparable percentage in Japan had grown from 40% to 60%; Germany 41% to 49%; France 34% to 42%; U.K. 39% to 44%; and the U.S. 44% to 47%.

Much of Canada's lagging R&D performance can therefore be explained by our low-tech industrial structure. And most significantly, this unhealthy characteristic is changing very slowly. The remainder of the gap, relative to other industrialized countries, is due to the low propensity of many Canadian firms to conduct R&D, reflected by the fact that R&D spending by many Canadian industries is a much smaller percentage of sales or value-added than is typical of the *same* industries in other advanced economies. The Canadian automobile industry, for instance, devotes a mere 0.3% of sales to R&D. This is barely one-tenth of the average relative R&D spending in the industry worldwide. In 1987, total expenditure by auto assemblers and parts manufacturers in Canada was less than $100 million as compared with a worldwide R&D outlay of about $10.5 billion by GM, Ford and Chrysler.[17] This amount was 40% greater than *total* R&D spending in Canada for that year.

Canadian steel producers spend only about 0.5% of sales on R&D, as compared with R&D spending by Japanese steel makers at 3.5% of sales. This has enabled the Japanese to transcend the "commodity" steel business and to dominate many specialty markets where the ability to meet extremely demanding customer specifications ensures healthy profit margins.

To take one further example, in 1987 the Canadian pharmaceutical industry spent only 3.5% of sales on R&D, an extremely low proportion by international standards. The government's drug patent protection legislation was motivated in part by undertakings by pharmaceutical manufacturers to significantly increase the amount of R&D in Canada.

The remarkably low propensity of many Canadian industries to perform R&D is graphically illustrated in Figure 16, which compares actual R&D spending in a representative sample of Canadian industries with potential spending if Canadian firms in each industry had achieved a ratio of R&D to sales equal to the OECD average.

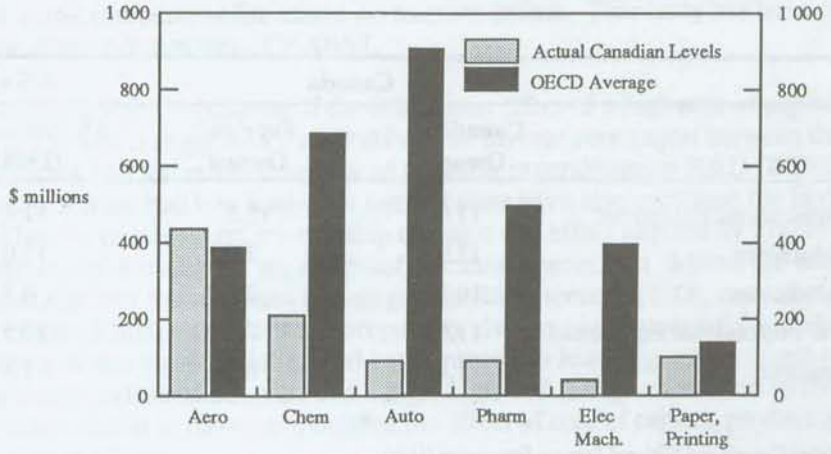
Thus, for example, if the Canadian auto industry (parts and assemblers) had a ratio of R&D to sales equal to the average of industrial countries, spending on research and development in 1987 would have been about $910 million. In fact, it was approximately $90 million. Similar huge gaps between actual spending and the industrial country average are found in the chemical industry, in pharmaceuticals and in electrical machinery. Even in the paper and printing sector, where Canada has a world-scale indigenous industry, relative R&D spending was below the OECD average. In the aerospace industry, on the other hand, R&D spending in Canada slightly exceeded the norm of other industrialized countries in 1987.

---

16 "Reassessing American Competitiveness"; monograph prepared for the National Planning Association (U.S.) by Peter Morici, 1988; p. 98.

17 Source: "Product and Process Development in the Canadian Automotive Sector;" Automotive Directorate; Industry, Science and Technology Canada (ISTC); January, 1990; p. 1.

Figure 16. Comparisons of R&D Spending (1987)



Source: Organization for Economic Cooperation and Development (OECD)

The Defence Industry Productivity Program (DIPP) provided major financial assistance and demonstrates that government encouragement can have a significant effect on R&D performance. For example, programs like the DIPP can be determining factors in the granting of world-product mandates to Canadian subsidiaries of transnational firms.

Those industries in which Canadian R&D propensity is particularly low tend to have a high degree of foreign ownership or to be specialized (at the sub-industry level) in lower value-added products. The Science Council of Canada is presently examining in depth the R&D performance of a number of industries. The results of this work will shed important light on the extent of, and reasons for, Canada's under-investment in R&D.

Some data (Figure 17) already suggest a strong inverse correlation between the level of foreign ownership and R&D expenditure, measured as a percentage of sales.

We have already seen that a number of major industries having a large foreign ownership component, such as automobiles, chemicals, electrical machinery and pharmaceuticals, perform little R&D in Canada. The data in Figure 17, covering a limited sample of subsectors, indicate that R&D spending by *Canadian-owned* companies is comparable with the amounts spent by companies in the U.S. in the same sector. Most *foreign-owned* companies in Canada, on the other hand, exhibit a very weak propensity to conduct R&D in this country. Although not included in Figure 17, the Canadian auto parts industry provides further evidence. While Canadian-owned auto parts firms accounted in 1986 for only 17% of shipments by the domestic parts industry, they performed 46% of R&D in the entire automotive sector — parts and assembly combined.[18] The data in Figure 17, while not conclusive in view of the small sample of sectors, nevertheless suggest that the branch plant nature of many Canadian manufacturers is one of the primary factors responsible for the feeble R&D statistics for the economy as a whole.

18 Automotive Directorate, ISTC, op. cit.

Figure 17. Impact of Foreign Ownership on R&D Spending by Companies: R&D As a Percentage of Sales (1987)

	Canada		USA
	Canadian-Owned	Foreign-Owned	All Companies (1986)
Telecommunications Equipment	17.0	15.5	11.4
Business Machines	12.9	2.9	12.0
Drugs & Medicines	10.7	2.6	8.3
Scientific & Professional Equipment	11.0	0.9	10.5
Metal Fabricating	1.8	0.7	1.4

Source: Statistics Canada and National Science Foundation (U.S.)

There is evidence that foreign-owned manufacturers in the United States exhibit no reduced propensity to perform R&D, and often do more than their U.S. counterparts. Some academics have argued that this proves that nationality of ownership is *not* a factor in choosing the location of R&D activity.[19] According to this view, transnational corporations scan the globe for hospitable R&D environments — e.g. clusters of trained people and support activities, favourable tax environments — regardless of country. These conclusions are not necessarily in conflict with the data in Figure 17 because Canada may simply be perceived by many foreign firms as not an ideal environment for R&D activity.

Market size has probably also been a factor in the different R&D location behaviour between Canada and the U.S. When a foreign firm establishes a significant presence in the U.S., it is less likely to be configured as a branch plant than if it were being located in a much smaller market such as Canada's. Therefore, foreign ownership may interact with small market size to produce low R&D propensity in Canada but not in the U.S., Japan, Germany and other large and/or technologically sophisticated economies. This question should be examined in depth, since it is increasingly important that Canada develop policies to attract a significantly larger share of global R&D activity.

The reasons for this importance are two-fold. First, research and development activity provides high-quality jobs, creating opportunities for Canadian scientists and engineers to remain in this country and inspiring more young Canadians to pursue technical careers. Second, without a solid base of R&D activity, many firms will lack the skills and corporate culture to embrace continuous innovation. And while the great majority of R&D used in Canada will inevitably be acquired — one way or another — from elsewhere, the capability of many Canadian firms to adopt and adapt leading-edge knowledge and techniques depends on their having a reasonably strong base of indigenous R&D activity.

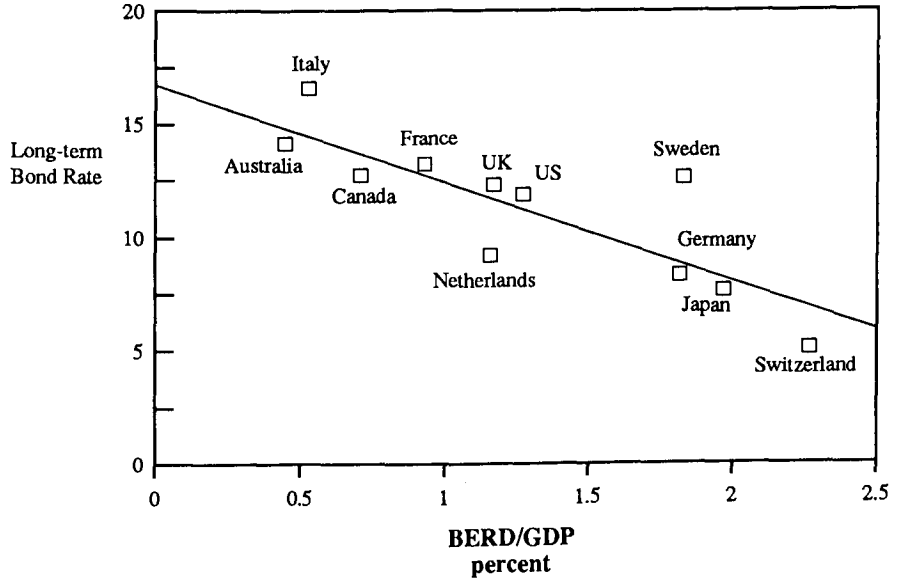
---

19 This thesis has been argued in an influential paper by Professor Robert Reich of Harvard – "Who is Us?"; *Harvard Business Review*; January-February, 1990; pp. 53-64. A partially opposed view has emerged from the research of Professor Michael Porter ("The Competitive Advantage of Nations"; op. cit.)

There is evidence suggesting that Canadian firms under-invest in R&D because of the high cost of capital in this country. In these circumstances, the longer-term payoffs typically associated with R&D projects, when discounted at a rate reflecting a high cost of capital, lose out in the competition for scarce investment dollars. This issue has been examined in depth by another committee of NABST.

Some support for the hypothesis of the deleterious effect of a high cost of capital is provided in Figure 18, which suggests a remarkably close inverse correlation between the cost of debt financing and the relative amount of business expenditure on R&D (BERD). Those countries that have had low long-term interest rates have also exhibited the highest BERD ratios. There is no necessary relationship of cause and effect implied by Figure 18. Correlations, by themselves, are not proof of causal connection. Moreover, should it be concluded that low interest rates lead to greater R&D spending? Or, conversely, are those countries with a high intrinsic R&D propensity also the most successful economically, leading to low and stable inflation and consequently to low long-term interest rates? In Canada's case, industrial structure and a high degree of foreign ownership in the manufacturing sector appear to have compounded the effect of cost of capital, producing an unusually low BERD.

Figure 18. BERD*/GDP vs. Bond Rate: 1980–1986 average



* BERD: Business Expenditures on R&D.
Source: ISTC.

A Perspective on Human Resources[20]

Ultimately, productivity and competitiveness depend on people — people who are trained, well managed and well equipped. The foundation of these attributes is superior education.

Governments in Canada spend $45 billion a year on public education. This ranks close to the top in the world, both as a percentage of GNP and on a per-pupil basis. But the results of this spending are worrying. For example, 30% of students are dropping out before they finish high school. Statistics Canada reports that 38% of Canadian adults cannot meet most everyday reading demands. And a similar percentage lacks the math skills to follow a simple sequence of numerical operations. At the same time, the Canadian Engineering Resources Board forecasts that about two thirds of the jobs that will be created within the next 10 years will require at least 12 years of education. About half of the new jobs will require 17 years or more.

Even though all the evidence points to the growing importance of a technically skilled population, most young Canadians are not choosing to educate themselves for the jobs of the 21st century. University enrolments in mathematics, science and engineering are declining in absolute numbers. The same is true for the technical trades. Meanwhile, manufacturers are complaining of acute shortages of workers with appropriate skills. Obviously something has gone very wrong, because the Board estimates that Canada will be short at least 10,000 engineers by the end of the decade — yet the educational pipeline is drying up.

Figure 19 shows that enrolment in the technology programs at Ontario Colleges of Applied Arts & Technology has fallen steadily between 1984 and 1988 — down 26% in absolute numbers (the bars) and from 27% to 20% of total enrolment (the line). This trend, which is mirrored across Canada, is particularly alarming because it implies a lack of interest in acquiring the basic, practical technical skills required to run a modern economy.

These apparent shortcomings of our formal education system are not being offset by workplace training. For example, the average Canadian worker receives about seven hours of training per year, whereas the average Japanese receives 200 hours and the average Swede receives almost 170. The Japanese and the Swedes — and the Germans, the French, the Finns, the Koreans and so on — are training their populations in a vastly more sophisticated set of skills and activities than is the case in Canada.

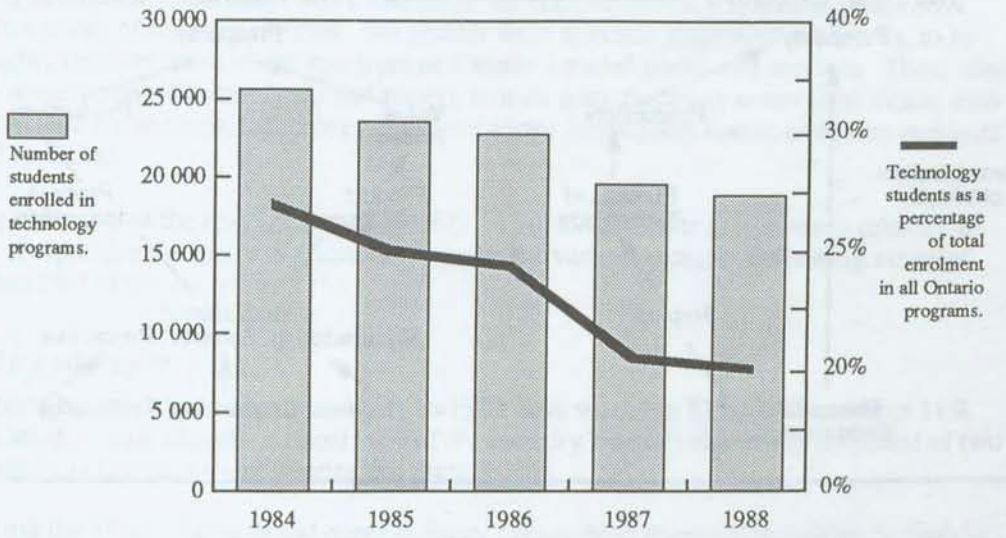
It might be assumed that Canada can rely, as it always has, on a continued inflow of technically skilled immigrants. But that source is already drying up. Forty percent of the immigrant PhDs currently resident in Canada arrived in the decade between 1967 and 1976. Fewer than 20% arrived during the following ten-year period. Three quarters of the foreign students enrolled in doctoral programs in Canada profess an intention to leave the country when they graduate.

Shortages of highly qualified people now exist the world over, even in countries like Germany and Japan. These shortages can only increase as growth in the labour force slows down and potentially huge demands materialize in Eastern Europe and Asia. If anything, Canada faces a brain drain as the United States struggles to improve its base of skills and begins to offer even greater attractions to Canada's best and brightest.

---

20 This section is abbreviated since matters related to education and training are addressed in detail in the Report of the Human Resource Development Committee of NABST. See *Learning to Win: Education, Training and National Prosperity*, available from the Communications Branch, ISTC. Statistics cited in this section are from the report, unless indicated otherwise.

Figure 19. Technology Programs Enrolment in Ontario Colleges of Applied Arts and Technology (1984-1988)

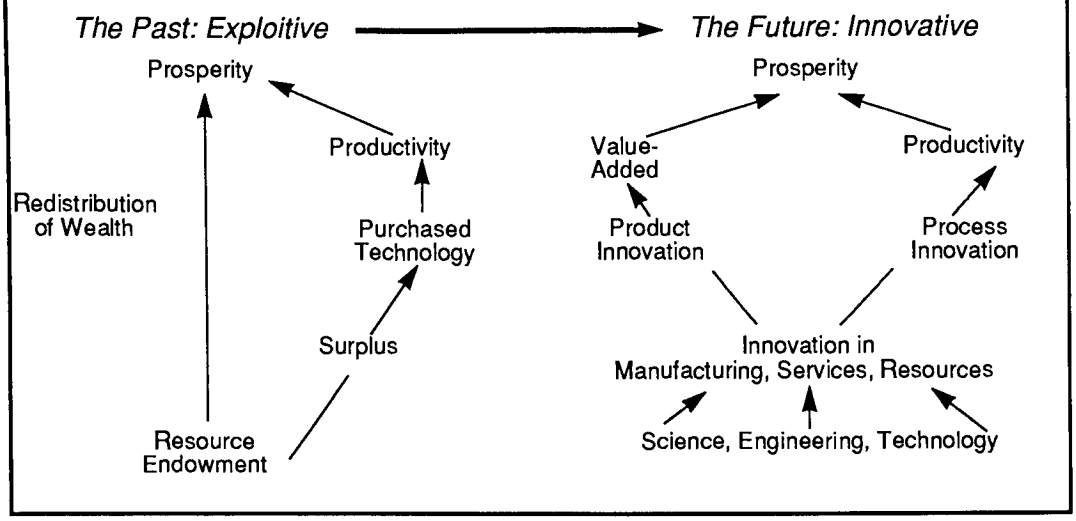


Source: College Affairs Branch, Ontario Ministry of Colleges and Universities, June 1989

Conclusion

The foregoing evidence, taken in its entirety, shows that Canadian industry is not well-positioned "to compete with the best in the world." The traditional foundation of Canada's wealth — the economic surplus from abundant natural resources — can no longer be relied upon to sustain the aspirations of an extremely affluent population. There is abundant evidence that the international competitiveness of many Canadian firms is eroding in the face of a harsh domestic macroeconomic environment and lagging productivity. We Canadians have been much slower than our competitors to recognize that the links between science-based technology, innovation, productivity growth and value-added constitute the primary source of economic growth in highly developed societies. The central long-term objective of policy should be to foster conditions in Canada that help these linkages to be created, strengthened and multiplied. The urgent challenge, depicted in the schematic diagram in Figure 20 (see next page), is to bring about a fundamental change of course — from an economy in which the primary source of prosperity has been the exploitation of natural resources, to an economy in which prosperity comes primarily from innovation.

Figure 20. Routes to National Prosperity



Competitiveness: An Industry Perspective

The foregoing diagnosis of Canadian competitiveness examined issues primarily at the level of the entire economy. The Committee has complemented this macro-perspective with a series of industry reviews. Six sectors were selected, somewhat arbitrarily, to be roughly representative of the spectrum of Canada's traded goods and services. These were: the resource-based sector (pulp and paper); mature manufacturing sector (chemicals; auto parts); and the modern, technology-intensive sector (aerospace; lasers; computer software and services).

The objective of the reviews was to identify, in broad terms, the major issues relevant to the competitive prospects of Canadian firms in the various sectors. Following are brief summaries of the six reviews.[21]

Pulp and Paper

Exports by the pulp and paper industry in 1989 were valued at $15.4 billion, about 11% of Canada's total exports. Almost 90% of the industry's export shipments consisted of two commodity products — newsprint and market pulp.

During the 1980s, the pulp and paper industry experienced dramatic swings in profitability and overall economic performance (see Figure 2 in the last section). In the early to mid-1980s, Canadian firms suffered a traumatic period in which low product prices and difficult competitive conditions were made worse by high interest costs on debt incurred to finance a wave of investments and acquisitions in the late 1970s. Moreover, a number of significant structural shifts have occurred in the world market for pulp and paper products, and in the industry itself, which threaten the capability of the domestic industry to generate future growth and prosperity on a sustained basis. Given the dominant role of pulp and paper in Canada's export trade balance, any threat to the industry's prosperity implies grave consequences.

Despite booming sales of market pulp and newsprint from 1986 to 1989, Canada will soon reach its potential for major expansion as the available softwood resource reaches the limit of sustainable development. While world demand for softwood kraft pulp will continue to expand at a moderate rate, competition from other pulps — particularly hardwood kraft and mechanical pulp — and from new suppliers such as Chile is expected to increase significantly. At the same time, the industry's customers, especially in the U.S., are moving toward fully integrated paper making facilities in an effort to reduce costs.

Although the Canadian newsprint sector continues to enjoy a strong competitive position — owing to a high-quality fibre base and low hydroelectric costs — projected fibre supply limitations will erode Canada's ability to meet rising world demand for newsprint in a cost-efficient manner. While Canada is obviously in no danger of literally running out of wood, limited incremental softwood fibre availability severely restricts the expansion prospects of the domestic industry.

---

21 Each sector encompasses a wide range of individual firms that face a diversity of competitive circumstances. Accurate generalizations are impossible. The original studies were prepared for the Committee by an outside consultant. The summaries included here have been reviewed by sector specialists in ISTC, but responsibility for choice of emphasis rests with the Committee.

Of particular concern is the growing number of customers in the U.S. who are insisting on recycled fibre content in newsprint. State regulations are pushing toward a standard of approximately 40% recycled fibre to new fibre. Canada's small population cannot supply adequate volumes of used newspapers and so, wherever feasible, the extra recycled fibre will have to be imported. More likely, the next generation of newsprint manufacturers will tend to locate close to the mass market where recycled fibre is abundant. Canada's comparative advantage would then be increasingly limited to raw pulp supply.

The only segment that presents the Canadian industry with substantial latitude for new investment and growth is the market for higher value-added printing and writing papers and other fine papers that require high-quality virgin fibre (such as super-calendered and light-weight coated papers used in advertising inserts, magazines and catalogues). Although most Canadian producers have traditionally ignored this market, it has expanded more rapidly during the past two decades than any other segment of the industry. Global demand now exceeds 50 million metric tons annually, almost double the size of the world newsprint market.

The Canadian pulp and paper industry, with a few notable exceptions, has nevertheless concentrated on lower value commodity products. The market for higher value products has been captured by American, European and Scandanavian firms. Despite an unprecedented wave of capital spending by the Canadian industry in recent years, printing and writing papers still account for less than 15% of the industry's total capacity.

Two factors appear to explain the long-standing commodity bias of the Canadian pulp and paper sector. First, an abundant supply of cheap wood and power ensured decades of easy profitability with correspondingly little pressure to develop alternative niches. Second, Canadian suppliers — unlike their U.S. and European competitors — were not constantly face-to-face with demanding final customers for specialized paper products. Trade barriers also impeded Canadian exports of higher valued papers. The Canadian industry thus failed to develop as keen a marketing orientation as its competition, seeing itself instead as an efficient, high-volume "producer." A similar production orientation has been characteristic of virtually all of Canada's resource industries.

Today, the realities of competition from new primary suppliers; the challenges and opportunities posed by the Canada-U.S. Free Trade Agreement; the constraints imposed by recycling requirements; and the enormous cost and complexity of environmental protection are combining to force the Canadian pulp and paper industry to radically and urgently adjust its traditional strategy in the direction of higher value products, even more sophisticated technology, and greater emphasis on market development.

The industry faces a particularly significant investment and technological challenge regarding environmental issues, as a result of increasing public and regulatory pressures. There is an immediate need for greater research to develop new technology; to increase reforestation; to recycle; and to control pollution from production processes. (The lack of scientific knowledge of the environmental impact of pulp and paper production is illustrated by the fact that only a few years ago was it discovered that chlorine-bleached kraft pulp produces minute quantities of dioxins and furans.)

Although the required re-orientation is widely understood and accepted, the industry's capacity to change quickly enough is limited by a shortage of appropriate skills, experience, and capital. Technological sophistication and a solid R&D base are, by and large, lacking in Canada. The innovative capability of Canada's most important resource industry is about to be severely tested.

Chemicals

In 1989, Canadian exports of manufactured chemicals totalled $6.9 billion, down 9% from the previous year. Major segments of the Canadian industry, largely foreign-owned, exhibit characteristics of the classic tariff-protected branch plant. A large number of businesses are being severely challenged by loss of tariff protection following the Free Trade Agreement (FTA) — most tariffs are being phased out over five years. Those plants that do disappear are likely to be those that would have failed in any event; the FTA appears at most to be an accelerator. The adverse macroeconomic conditions — particularly the high dollar — have posed a greater immediate threat.

During the 1980s, most international producers have shifted resources away from the low-valued commodity chemicals (the basic building blocks and simple intermediates) in response to shrinking profit margins and global overcapacity. Canadian producers of petrochemical products lost their feedstock cost advantage with the move to world prices, but they remain competitively located — particularly those in Montreal and Sarnia — in relation to many major U.S. markets. There is, nevertheless, a strategic risk from potentially very-low-cost producers, in the Middle East and the Soviet Union, for example.

Highly industrialized countries have focused their activities on higher value-added products, typically in the formulated or performance-tailored chemicals field. The world market for these specialty chemicals as a whole is expected to increase 6 to 9% per annum during the next 10 years — more than double the rate of growth anticipated for commodity chemicals.

The Canadian industry has generally been constrained from expanding in specialty chemicals because of a lack of technological capability. The present R&D capabilities of the Canadian chemical industry fall short of what is required to produce a continuous stream of innovative products and processes needed to support a globally competitive specialty chemicals industry. The expertise to develop proprietary production processes, specialized formulation skills and applications engineering capabilities in specialty chemicals, does not exist on a significant scale in Canada. The marketing expertise and distribution channels needed to succeed in the global specialty chemicals market are therefore also absent in the case of most Canadian-owned companies, though they exist potentially in the case of foreign subsidiaries.

Most Canadian producers have been prevented from making major investments in world-scale specialty chemicals facilities by their foreign parent enterprises, which typically have established plants in the United States to serve the North American market. A lack of strategic autonomy has diminished the ability of Canadian industry to expand export markets and to make the investments in R&D needed to be internationally competitive in higher value-added products.

The key to survival for much of the industry now lies in acquiring mandates to provide higher value-added products in world markets. Adequate production volumes are essential to cover up-front development and capital costs. Success in export markets is therefore a *sine qua non*. So while the FTA has threatened the prospects of many segments of the existing industry, the Agreement does offer the best opportunity for the Canadian chemicals industry to adjust toward new high-value products. The challenge is to convince transnational chemical producers that Canada is a suitable host for the manufacturing of certain sophisticated products that will have a North American, if not a global, market mandate.

Automotive Parts

Canadian auto parts exports in 1989 were $10.8 billion, virtually the same value as in 1984. Imports in 1989 were $16.8 billion, also little changed over the past six years.[22] There are approximately 425 firms engaged primarily in the sector, with a further 1,500 less directly involved.

If Canadian auto parts manufacturers are to survive, many will have to continue adapting to the radically new design and production philosophy that has emerged from Japanese practice. Japanese firms are making the management of the innovation process the key competitive issue of the 1990s, just as they did with cost and quality in the 1980s. Historically, the Canadian parts industry operated on a "build-to-print" basis and competed primarily on cost. Almost all of the R&D incorporated in parts and subassemblies was undertaken by assemblers. Most parts suppliers therefore saw no need to perform R&D themselves, or to acquire advanced technical skills. They were content to specialize in responding quickly to the needs of assemblers for process and tooling modifications.

Many Canadian parts manufacturers have made impressive strides in quality and productivity improvement during the 1980s. They benefited from extensive technology transfer from parent companies — primarily GM, Ford and Chrysler — and were also successful in adapting the latest Japanese production techniques on the shop floor.

But the critical competitive factors in the industry are changing quickly as North American assemblers embrace the evolving "lean manufacturing" model for the rapid development of automotive products. This model is based on new materials and advanced electronics, continuous incremental improvement in production processes, and close links between design and manufacturing ("concurrent engineering"). This has triggered a redefinition in North America of how, and where, many R&D activities should be performed. Assemblers are moving components of production closer to final assembly plants in order to design for function and manufacturability simultaneously. The biggest auto parts producers will be expected to work in tandem with assemblers in the design of subassemblies for new models. Assemblers will demand that these major suppliers not only produce parts, but also provide design and engineering expertise in the development of new products incorporating advanced technologies.

Much of the Canadian parts industry is relatively ill-equipped to meet these changing conditions. Its R&D, engineering and technological capabilities are weak. Many Canadian parts manufacturers will be challenged to acquire the appropriate engineering staff and the in-depth knowledge of the design process required by assemblers.

The major barriers to expanding the technological capabilities of the parts industry include an acute shortage of automotive engineering and technical personnel; inadequate training facilities; and a reluctance on the part of smaller suppliers to commit capital to risky technology-development initiatives, particularly without assured purchase commitments from assemblers. If the industry fails to meet the challenge in the near-term, it faces the prospect of a steady erosion of domestic production and jobs. In the globalized automotive industry there will be no room for low-technology manufacturers operating in high-wage countries.

---

22 Data are from *The Bank of Canada Review* (September 1990). Figures for 1989 cited by ISTC indicate parts exports of $11.7 billion and imports of $20.5 billion (excluding tires and tubes).

Aerospace

Shipments of Canadian aircraft and parts in 1989 totalled $6 billion, of which approximately 70% were exported.[23] Sales have grown at a compound average rate of 13% since 1983. Trade in the sector as a whole is roughly in balance. The industry is a heterogeneous mix of companies that face a variety of challenges and opportunities that defy easy generalization.

International competition in aerospace has traditionally revolved around technological, political and market-share factors. More recently, price competition — and the consequent need to control costs — has become increasingly dominant. Technical capability obviously remains essential for gaining entry, and in some cases products can be differentiated on a technological basis. In most business segments, however, the key determinant of success is securing adequate assured sales over which to amortize the fixed costs associated with R&D and the launch of new products.

In the past, military projects often provided the technical and financial cushion required to support civilian aerospace activities around the world. The almost risk-free revenues from "cost-plus" military work allowed firms to take on high-risk civilian projects while maintaining an acceptable overall risk profile. And while military orders still form an important underpinning in significant parts of the world industry, much defence work is now contracted at fixed prices and has thus become quite risky.

Canadian aerospace manufacturers have achieved, over the past two decades, a remarkable reorientation of their production from a military to a civilian emphasis. Civilian work now comprises about 70% of sales. Of the 20 major Canadian firms in the sector, only two still have a preponderance of their activity in the defence sector. The reorientation of the industry has depended on the ability of Canadian manufacturers to become world competitive in a number of important niche areas — some examples are Pratt & Whitney's PT-6 Turbo Fan engine; Bell Helicopters; CAE's simulators; and many other products that have met the price and quality demands of international commercial customers. It is also true that significant defence procurements, such as the CF-18 aircraft program and NORAD modernization, have given a strong boost to the industry's growth.

Canadian aerospace manufacturers have evidently developed a strong base of technological capability in a number of product niches. The sector is one of the few in which R&D spending in Canada is comparable with industrial country averages (see Figure 16). This level of R&D spending has been fostered by R&D support through the Defence Industry Productivity Program (DIPP). The industry has also benefited from a great deal of technology transfer from parent corporations, primarily in the U.S. Some Canadian manufacturers have world product mandates, and in certain cases (such as Pratt & Whitney's development of smaller-engine technology) Canadian firms are providing significant reverse technology transfer to the foreign parent.

Notwithstanding the serious concern of some companies in the face of defence cutbacks, the Canadian aerospace industry as a whole has been forecasting continued strong sales growth, with an approximate doubling between 1989 and 1993. (These overall forecasts are now being scaled back in light of the economic slowdown and continued pressure on Canadian cost competitiveness.) The progressive orientation of the Canadian industry

---

23 Figures based on industry data compiled by ISTC. Trade data reported in *The Bank of Canada Review* show export sales somewhat lower, at $3.6 billion.

toward the civilian sector has reduced the vulnerability of most firms to defence cutbacks in the U.S. and elsewhere. Moreover, if development of new weapons systems is scaled back, the demand for repair and overhaul work is likely to increase. And this is an area where many Canadian firms are very competitive.

Although there are solid grounds for optimism in Canada's aerospace sector as a whole, the industry is not without significant challenges. The adverse trend of unit labour costs, described earlier, is of immediate concern. Canada tends to focus on the civil commuter aircraft market, where there is high demand but significant over capacity worldwide. The inevitable rationalization in this sector, combined with a squeeze on defence spending, may make Canadian exporters vulnerable. While outright subsidization of aerospace firms is officially discouraged by virtually all countries, there is nevertheless intense international competition to attract and retain jobs in this prestigious, technology-intensive industry. Increasingly, governments have taken direct ownership positions in the industry, a factor that changes fundamentally the nature of competition. On the military side, there is the prospect of major contractors in the U.S. diversifying into the civil sector, adding to the competitive pressure. And faced with tighter conditions, it is likely that the U.S. will tend to favour its domestic industry through a bias toward procurement of systems that have a higher proportion of U.S. domestic content.

Apart from the uncertainty caused by political and macroeconomic factors, the Canadian industry faces three key technological challenges. The first is that the aerospace sector is undergoing a structural change in which the prime assemblers are demanding increased technological capability and innovation from their key suppliers. (The same trend has already been noted in the auto parts sector.) The Canadian aerospace industry is increasingly required to provide the basic design, engineering and R&D required for continuous innovation. The investments needed are often high-risk ones, since typically there is no guarantee of sufficient sales volumes to amortize the upfront costs.

The second fundamental problem is the chronic shortage of skills in the aerospace sector. Canadian firms have often relied on attracting a significant amount of highly trained talent from abroad — particularly Europe — but these sources are drying up or becoming extremely expensive to tap. The significance of the skills shortage can only increase as the above-noted technological demands on Canadian suppliers grow.

The third challenge is to seize the opportunity created by the growing international concern with global environmental change. Canada's space industry has developed expertise in remote sensing satellites, ground stations and data analysis. This technology will be heavily used in the coming decades by the various international "global change" programs, and this presents an opportunity for Canadian industry to occupy an important niche.

The Canadian aerospace industry has been, overall, one of the success stories of the manufacturing sector, and has proven that Canadian firms are capable of establishing world competitive niches in technology-based production. But it is equally clear that maintaining its share of the global aerospace market will require a continuation — and perhaps intensification — of supportive government policy as well as an all-out commitment to skills development at every level.

Lasers

Between 1980 and 1986, worldwide sales of laser-based products doubled from $400 million to $800 million as the variety of technologies and the number of applications for lasers rapidly expanded. Since then, the growth of applications for lasers and other light-related (photonic) products has been explosive. Lasers have emerged as a global "strategic" technology. Rapid development has been spurred by extremely generous government support for R&D in Europe (particularly in Germany) and Japan, and through defence outlays in the U.S.

The basis for competitive advantage in the laser industry depends on the ability to continually meet new product developments of competitors. Scale in production, marketing and service coverage are of increasing importance. Even well-entrenched industry leaders have found it necessary to seek strategic alliances and joint ventures with other enterprises (often non-laser firms) to facilitate their entry into new markets and to finance continued growth. The recent entry of Japanese laser companies into the world market with low-cost semiconductor diode lasers has accelerated a process of rationalization and large-scale manufacturing.

Canada's only serious contender in the world laser industry is Lumonics Inc., the third-largest manufacturer of high-powered laser-based products in the world. The company has annual sales approaching $90 million and subsidiaries in the U.S., Germany, Japan and the U.K. It affords an instructive case study of the commercialization of high technology in Canada.

Lumonics was established in 1970 as a by-product of federally funded research and development at the Canadian Defence Research Establishment in Valcartier, Quebec. The company's history has been marked by one research success after another in the development and manufacture of lasers. This success was due to a commitment to R&D; the rapid growth in world demand for laser technologies; financial and technical assistance provided by federal and provincial governments; and the significant laser research and development infrastructure within the National Research Council, the University of Toronto, and McMaster and York Universities.

Despite these advantages, by the end of 1986 Lumonics found itself in a precarious competitive position. The company was still dwarfed by its two major U.S. competitors, Spectra-Physics and Coherent Inc., which were up to four times larger than their Canadian rival. Also, these companies had entered into strategic partnerships with financially powerful corporate backers, such as Ciba-Geigy and General Electric, to enhance their R&D, marketing, and product development capabilities in response to intensifying competition from major Japanese manufacturers.

Lumonics, meanwhile, had been unable to garner corporate alliances of comparable scale and was forced to invest a minimum of $5 million in R&D annually simply to maintain the company's existing product line and sales volume. Since new product development activities required investments in R&D over and above this base level, Lumonics was forced to "bet the company" every time it attempted to develop a new product or process. The company's major competitors could readily afford to sustain large investments in R&D, even during periods of faltering sales and fierce competition, because of the support they received from corporate backers and the U.S. government. Lumonics could not follow suit.

After three successive years of financial losses (1986-88) — largely attributable to intense competition in the North American market and to heavy expenditures on R&D — Lumonics finally signed an agreement with Sumitomo Heavy Industries of Japan. Sumitomo agreed to purchase all of the company's outstanding shares for $83.7 million. In approving the takeover, the federal government obtained the agreement of Sumitomo to provide financial support for R&D in Canada — guaranteed to be at least 10% of sales — as well as to support marketing activities. Lumonics has become the only North American laser manufacturer in its field to crack the Japanese market.

Although Sumitomo had no previous experience in laser production, it was prepared to offer Lumonics the one element that Lumonics had been unable to acquire in Canada: access to large pools of patient risk capital that Sumitomo was willing to commit to the laser business on a long-term basis. This was the critical ingredient that Lumonics needed to ensure its survival.

Computer Services and Software

The Canadian computer services and software industry is one of the fastest-growing segments of the economy, with sales of approximately $4.6 billion in 1988. Reliable trade figures for the industry are difficult to obtain.

The competitive dynamics of this industry have shifted in recent years from innovative capability alone toward product differentiation, scale in marketing, distribution, and R&D activities. Yet it remains a highly entrepreneurial industry, typically populated by inspired individuals. Start-up firms usually market their initial products in both domestic and foreign markets. By the time firms have achieved annual sales of about $2 million, they are generally experienced exporters of software or services in competitive North American market niches and sometimes overseas.

Success in this strategy requires a clear understanding of relevant market niches, a highly visible local presence in major markets, and strong on-the-ground marketing, distribution and service networks. These are costly to establish and maintain. Most Canadian vendors of software and computer services lack the financial resources and "critical mass" required to realize this option.

The difficulty is compounded by the widespread inability of the industry to secure adequate debt or equity financing from financial or other institutions in order to fund needed investments in R&D and international marketing. The small, recently established firms that make up the industry are frequently short of financial management and marketing expertise. With limited capital and an asset base that typically consists almost entirely of intellectual property — which lenders are usually unwilling to accept as collateral — the typical Canadian software company is cut off from traditional bank financing and venture capital. While access to conventional financing is therefore a constraint on growth, there are ways to fund working capital needs (sometimes by selling, or "factoring," accounts receivable to specialized financial intermediaries).

Probably more basic than the financing issue is the challenge to penetrate export markets in a significant way. Some Canadian software houses have been very successful in this regard — the Toronto-based computer graphics firm, Alias, for example — proving that the task can be accomplished with the right combination of marketing and technology.

The growth prospects of the sector are perhaps most fundamentally threatened by an alarming decline in the rate of new graduates in the computer field. University enrolments in the relevant subjects are estimated to have declined 30% since 1983. Given that the industry is built almost entirely on intellectual capital, this will be a devastating trend if it persists.

Conclusions

It is apparent, even from this limited sample of industry reviews, that competitive circumstances and challenges vary widely from industry to industry. Perhaps the most fundamental, common problem is the chronic shortage of highly skilled employees. This shortage threatens to become even tougher in light of declining enrolments in fields of technical education in Canada, combined with increased global competition for engineering and other technical skills. Despite the diversity of issues facing Canada's various industrial sectors, there is a pattern that suggests that these industries fall in a number of generic categories.

The mature industries, such as pulp and paper, risk being caught in a "commodity trap." In a sense, the chemical industry and the domestic auto parts sector also fall into this category because these firms have typically failed to develop an innovation culture. They have not invested sufficiently in the R&D needed to keep up with their peers in other industrialized countries — countries where there has been much greater recognition of the need to move up the value-added chain while shifting standard products and processes to low-wage countries. Mature Canadian firms have typically failed to follow suit. Consequently, a number of large industries in this category face bleak long-term prospects unless they succeed in transforming themselves radically and rapidly.

A second category, represented by a substantial segment of the Canadian chemical industry and many consumer-goods producers, is comprised of firms that have remained truncated as a consequence of foreign ownership and branch plant status. Very few have been granted world product mandates. They have not developed skills in product and process innovation, nor in international marketing. Most are unlikely to survive global competition unless their transnational parents provide them with export mandates.

The third category, which includes the aerospace, telecommunications and nuclear industries, comprises mature firms with proven technological capability. A major challenge facing these firms is that they depend on very large contracts in markets where government subsidies and procurement preferences are virtually essential. Companies based in small countries like Canada are particularly challenged to overcome both political favouritism in export markets and the highly competitive export financing packages offered by many industrialized countries. Firms in this category cannot hope to survive without supportive and focussed government policies.

The final category comprises newer, technology-intensive industries such as lasers and computer software. These firms, the vast majority of which are in the embryonic or juvenile stage of development, typically have world-class technological capability and excellent R&D propensity. Invariably, their principal challenge is to acquire sufficient financial backing to support growth to an internationally competitive scale. This has proven to be particularly difficult in Canada because the domestic venture capital market is weak; institutional investors and financial institutions shun immature businesses with few tangible assets; and very large established corporations, e.g. the resource-based conglomerates, have exhibited little willingness to provide heavy support for technology-based enterprises.

The foregoing synopsis reveals a Canadian dilemma that contains both a problem and an opportunity. Canada has a number of high-potential, technology-based companies in sectors that have excellent long-term growth prospects. But these companies usually lack sophisticated financial management and marketing expertise. They are also unable to attract sufficient capital to nurture them past the threshold where they could become major exporters themselves, or strong suppliers to exporting companies. Meanwhile, Canada has many capital-rich companies — typically based directly or indirectly on the resource sector — that possess abundant financial and marketing skills but that lack a "technological outlook" and have consequently failed to aggressively move their product lines up the value-added chain.

In other industrialized countries, large established companies are more prepared than their Canadian counterparts to adopt an innovation culture based on scientific technology. This is enabling such firms to maintain their own commercial vitality while also predisposing them to invest in young, technically precocious firms in high-growth sectors. They have been willing to exploit the natural complementarity between mature capital-rich firms and juvenile capital-poor firms; and established corporate skills (e.g. financing and marketing) in the mature firms and technological vigour in the young ones. The challenge, and the opportunity, facing Canadian industry is to exploit this natural complementarity and thereby provide the means by which our industrial structure can be continuously transformed and modernized.

Summation

This report defined science and technology as the set of skills and activities that are linked, through innovation, to increased productivity, and which thus underpin economic development in advanced societies. The report has documented the widening gap between the technological fitness of Canadian industry and that of our industrial country competitors. The extent and seriousness of this gap must become widely understood so that governments, and Canadians generally, will act with commitment and urgency to change course.

The report has provided a diagnosis, still incomplete, but clear enough to demonstrate the need for a decisive change of course to reverse the erosion of the base of Canada's economic prosperity. The challenge must be met primarily by Canadians as individuals, and particularly by firms in sectors exposed to global competition. There is nevertheless an essential role for government to establish the most favourable possible conditions to encourage innovation and productivity. First, government must provide leadership and a sense of direction.

It is not easy to identify a set of practical and effective policy measures to address the pervasive problem described in this report. The present circumstances facing Canadian industry were long in gestation and have roots deep in our national psyche. Much of the problem is attitudinal and therefore resists conventional policy remedies. There are no quick or easy answers. Furthermore, there is no consensus among business people, scholars and policymakers — either here or abroad — as to the most effective way to proceed. The policy debate has been dominated by doctrinaire positions polarized between the disciples of the free market on one side and of aggressive government intervention on the other. Almost certainly, the whole truth lies somewhere in between.

Although the issues have been studied over the years in extraordinary breadth and depth, the evidence remains ambiguous. There are very few generalizations that survive transplantation from one nation to another. The effectiveness of any set of policies evidently depends on the particular historical, cultural and institutional context.[24] Nevertheless, there are at least three directions that Canadians can take with considerable confidence.

I. Policies that mobilize science and technology to promote innovation and increase productivity must move forward on several fronts simultaneously. The most important of these are:

- **Framework policies** that encourage the application of S&T, including regulatory policies that encourage, rather than impede, innovation; policies that promote national savings and thus reduce the cost of capital; policies that promote competition; and policies that facilitate adjustment;
- **Human resources policies** addressing the full spectrum of training and education with emphasis on inspiring more young people to pursue technical careers; providing much greater management and employee training; and developing in individuals the flexibility to adapt to continuous technological change; and
- **Policies to promote the development, acquisition and diffusion** of technology and state-of-the-art industrial practices.

---

24 It is essential, nonetheless, to be aware of the approaches to the competitiveness challenge taken by other nations. A great deal of background information in this regard was assembled for the Committee by the consulting firm, SECOR Inc.

II. Canada's circumstances suggest that the most urgent S&T challenges for the private sector, with the cooperation of government, are to:

- Employ science-based innovation and technology more effectively to increase the value-added in Canada's resource industries and in the mature manufacturing sector;
- Make Canada a more attractive location for the performance of R&D by Canadian and foreign-owned companies; and
- Create a climate that encourages the birth, growth and maturation of technologically sophisticated firms in high-potential sectors.

III. To ensure that policies in the forgoing areas are most effective, governments must engage in continuous consultation with the private sector to develop a shared understanding of the best ways in which science-based technology can be applied in particular sectors and sub-sectors to foster innovation and increased productivity.

Conclusion

The need for a fundamental change of course in Canada is clear. The approximate compass bearing for the new course can already be set — Canadians must become much more adept in applying science and technology to create a continuous flow of innovation and productivity growth. But the precise bearing to take is less clear. Finding it will probably require countless incremental steps — a process of trial, error and evaluation. But a determination to change course must be affirmed now. **It is therefore essential that the government accord the highest priority to the matters raised in this report.** By this act alone, a powerful creative force will emerge that will give rise to a wealth of constructive ideas. It will be a long journey, but it must begin with this first step.